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THE EFFECT OF SPECIFIC DIETARY FATS ON THE BLOOD LIPIDS OF LACTATING GOATS[1]

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Several studies (1, 2, 3, 4, 5) dealing with the relationship of the various blood lipids in lactating animals to the fat intake on the one hand, and to the milk and fat secreted on the other, have been reported from this laboratory. These studies have added considerably to our knowledge of the physiology of lactation, and made it evident that a consideration of these blood lipid relationships is of distinct value for obtaining a more exact understanding of the dietary requirements for maximum milk and fat production.

In our studies with cows dealing with the influence of different fat intakes upon the blood picture and upon production, the dietary modifications were limited to the partial or nearly complete extraction of the fat from the grain mixture and its replacement by starch. The results obtained suggested the desirability of ascertaining the effect of a more complete removal of the fat from the ration and the influence of specific kinds of fat. Since such studies with cows would prove very expensive, and impracticable in other respects, we were led to employ goats for the purpose. One report of this work has already appeared in this Journal (4). The present article describes further experiments involving a study of the amount and distribution of the various lipids in the plasma and cells, as influenced by specific oils and fatty acids, when substituted for starch in a fat-free ration.

EXPERIMENTAL PROCEDURE

In order to obtain a basal diet as free from fat as possible an extracted grain mixture was used as in the previous studies and regenerated cellulose was used as the roughage component in place of hay. This cellulose was a purified product practically free from ether extractible material. The grain mixture was made up as follows:

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[1] The data presented are taken from a thesis offered by H. H. Williams to the Graduate School of Cornell University in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

misprint.

20 parts	Hominy feed
20 parts	Ground oats
25 parts	Wheat bran
22 parts	Corn gluten feed
10 parts	Corn gluten meal
1 part	Bonemeal
1 part	Ground limestone
1 part	Salt

By extracting this grain mixture with 95% alcohol continuously for 3 days in an extractor designed by McCay (6), its ether extract was reduced to less than 0.2%. The fat thus removed was replaced by an isodynamic amount of starch. In addition to the grain mixture and cellulose the basal diet contained molasses, ether-extracted yeast, White's vitamin A–D concentrate and additional minerals. The molasses was used primarily for its effect on palatability. The yeast and A–D concentrate were added to supply vitamins. The minerals consisted of equal parts of bonemeal, limestone and salt plus 1% of ferrous sulfate and 0.1% of potassium iodide.

The oils and fatty acids employed as supplements to the basal diet were butter oil, coconut oil, a mixture of palmitic and stearic acids, and a mixture of oleic and linoleic acids. The butter oil represented the same fat as secreted in the milk. The coconut oil provided a nearly saturated fat having a fatty acid distribution somewhat similar to that of milk fat. The specific fatty acids used provided for a comparison of the effect of saturated fatty acids of high molecular weight (palmitic and stearic) with unsaturated acids of high molecular weight (oleic and linoleic).

Six goats, approximately one month along in their lactation, were used over an experimental period of 112 days, divided into four sub-periods of 28 days each, with the exception that the first sub-period was 31 days for four of the animals. During the first period each goat received the fat-free ration. During subsequent periods various diets involving the use of the fat supplements were employed as shown in table 2. It is noted in this table that in the case of four of the animals alfalfa hay was included in the ration during the final period. The reason for this is explained later.

Throughout the experiment, with the exception of the cases where alfalfa was fed, each animal received daily 200 grams of cellulose, 200 grams of molasses, 25 grams of extracted yeast, 20 grams of the mineral mixture, and 4 drops of A–D concentrate. The grain mixture, with or without fat additions, was varied from week to week according to the production of the animal during the previous week with the object of supplying digestible crude protein and total digestible nutrients in accordance with the animal's requirements. In general for a given animal the grain intake ranged between 400 and 600 grams daily. The entire basal diet as fed contained approximately 0.2% of fat. Where fat additions were made the amounts were governed by the amounts being secreted in the milk. Where alfalfa and

grain were fed these feeds were allowed *ad libitum*. The daily intakes of total digestible nutrients and of fat are shown in table 1. It is noted that the intakes of total digestible nutrients declined as the experiment advanced, with the exception of the last period where hay and grain was fed *ad libitum*. This is in part the result of a lower allowance due to the drop in milk yield and in part to frequent failures of the animals to eat their allowance completely. In the last periods for goats A, C, E, and F, it is probable that the *ad libitum* feeding of grain and hay resulted in an unnecessarily high intake of total digestible nutrients. The possibility that the animals were underfed when on the other diets will be referred to in discussing the milk yields.

TABLE 1

Daily intakes of total digestible nutrients and fat, averaged by periods

GOAT	PERIOD 1		PERIOD 2		PERIOD 3		PERIOD 4	
	T. D. N.	Fat	T. D. N.	Fat	T. D. N.	Fat	T. D. N.	Fat
	gms.	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*
A	771	2.2	650	50.6	549	1.6	956	14.4
B	591	2.3	364	12.9	357	14.2	334	1.0
C	670	2.2	603	36.2	589	34.1	1052	49.9
D	706	2.3	501	22.1	444	19.2		
E	647	2.0	500	26.5	490	18.9	900	13.5
F	634	2.0	505	24.8	476	17.3	1003	47.9

It was originally planned to take blood samples at the beginning, in the middle, and at the end of each period. After the first period, however, it was found that there was insufficient time for such a large number of analyses, and thus thereafter the sampling was frequently limited to one taken at the end of each period.

The blood plasma and cells were analyzed for total and free cholesterol, lipid phosphorus, total lipids, and the iodine number of the total lipids. The cholesterol analyses were carried out by Okey's (7) procedure as modified by Yasuda (8). The lipid phosphorus of the alcohol-ether extract was determined by Denige's procedure as modified by McCay (9). This was multiplied by the factor 18.26 to get the amount of phospholipid fatty acids. The total lipids were determined by Bloor's oxidation procedure (10) and the iodine numbers of the total lipids were obtained by the method of Yasuda (11).

RESULTS

In our previous experiments with cows and goats, it has been shown that the partial or complete removal of the fat from the grain mixture causes a decline in milk yield. In planning the present experiment, it was hoped to

obtain some definite information as to the influence of specific fats upon milk and fat yield as well as on the blood picture. While these records for yield were obtained, the detailed data are not being reported at this time pending the completion of a further experiment which it is hoped will answer questions now obscuring the significance of the present results. However, a brief statement regarding these data will be made for reference in connection with the discussion of the blood data, and to indicate the questions requiring further study.

In every case the fat-free ration caused a very rapid drop in milk yield and an equal or greater decline in fat yield. These declines ranged from 25 to 65% for the various goats from the start to the end of the period. In no case did the inclusion of a fat supplement in the ration have any effect on milk yield beyond arresting wholly or in part the decline on the fat-free ration, although the butter oil and coconut oil increased the fat percentage. Because of these results for milk yield, which were contrary to what we had obtained with cows, the question arose as to whether any system of feeding would cause any marked increase in milk yield in goats after they had experienced such a severe decline as occurred on our basal diet. To answer this question a ration of alfalfa hay and grain was fed *ad libitum* to four of the goats (A, C, E, F) in the final period. In two cases the grain mixture had been extracted, in the other two, not. In all cases the milk and fat yields rose markedly. However, as previously mentioned in referring to table 1, the consumption of total digestible nutrients was considerably greater than in the previous periods. Thus the results with the hay and grain, which answered the specific question causing them to be fed, raised the further question as to the significance of the results during the previous periods. It is possible that the large drops in yield during the fat-free period and the failure of the fat additions to increase the yield were due to an insufficient intake of food, although the animals maintained their weights throughout these periods. The superior results with the alfalfa ration may have been due merely to a larger intake of food, or to the removal of some specific unfavorable factor in the previous diets, or to the addition of an unrecognized essential in the alfalfa. These are the questions now under study.

The blood data are presented in table 2. It is noted that in some periods the analyses were made three times in a given period, in others twice, and in the remainder once, with the exception that in period 3 no blood sample was taken from goat B. Where only one analysis was made during a period the sample was taken at the close in order to measure the final effect of the diet over the 28 days.

The data for total lipids in the plasma show that in every case they dropped markedly on the fat-free diet. In the case of goats A and B, where this diet was followed by the one containing the butter oil, the total lipids

TABLE 2

The distribution of total lipids, total and free cholesterol, and phospholipids in the plasma and cells—milligrams per 100 cc. The iodine numbers of the total lipids

GOAT NO.	PERIOD	DIET	DAYS ON DIET	TOTAL LIPIDS				CHOLESTEROL				PHOSPHOLIPID FATTY ACIDS	
				Plasma		Cells		Plasma		Cells			
				Amt.	I. N.	Amt.	I. N.	Total	Free	Total	Free	Plasma	Cells
A	1	Fat-free	5	325	73	560	60	76	15	154	146	82	250
			19	300	66	553	64	65	17	140	131	73	217
			31	261	65	444	54	51	11	142	134	60	248
	2	Fat-free and butter oil	2	327	67	479	64	77	17	145	124	82	219
			25	482	68	503	53	129	30	155	147	137	267
	3	Fat-free	27	234	53	464	53	37	10	156	151	60	265
	4	Extracted grain & alfalfa	27	328	59	475	52	67	13	136	134	86	252
B	1	Fat-free	5	351	67	604	66	91	27	190	162	84	230
			19	300	59	552	65	45	16	.....	.....	57	245
	2	Fat-free and butter oil	1	279	55	546	64	54	13	157	145	68	245
			6	322	63	542	66	62	14	147	147	79	245
			27	351	73	525	70	80	20	143	143	102	267
	3	Unextr. grain & butter oil	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	4	Fat-free	3	322	63	559	66	60	14	136	136	82	265
			26	268	54	536	66	59	11	150	150	62	268
C	1	Fat-free	6	231	73	550	62	61	13	150	150	69	254
			20	194	71	563	63	53	9	157	155	58	256
			31	195	62	504	61	47	12	129	123	57	223
	2	Fat-free & stearic & palmitic acids	2	238	67	496	62	62	13	120	120	71	247
			25	308	62	529	58	86	19	141	138	91	245
	3	Unextr. grain & stearic & palmitic acids	27	295	65	533	60	73	17	141	115	86	223
	4	Unextr. grain & alfalfa	27	360	66	500	67	85	20	140	140	99	223

TABLE 2—(*Continued*)

GOAT NO.	PERIOD	DIET	DAYS ON DIET	TOTAL LIPIDS				CHOLESTEROL				PHOSPHOLIPID FATTY ACIDS	
				Plasma		Cells		Plasma		Cells			
				Amt.	I. N.	Amt.	I. N.	Total	Free	Total	Free	Plasma	Cells
D	1	Fat-free	2	374	76	492	63	101	23	129	120	108	225
			25	270	54	479	64	59	12	127	127	69	230
	2	Fat-free & stearic & palmitic acids	3	290	57	494	61	60	10	129	127	82	239
			27	333	58	512	59	78	16	128	127	99	237
	3	Unextr. grain & stearic & palmitic acids	27	344	66	506	60	85	20	135	121	110	237
E	1	Fat-free	7	282	72	553	60	76	16	143	137	84	236
			21	258	67	543	54	66	14	149	131	75	223
			31	200	67	448	55	56	19	138	124	70	237
	2	Fat-free & coconut oil	2	272	67	496	61	67	13	126	110	80	217
			26	239	57	425	57	61	18	131	131	75	247
	3	Fat-free & oleic & linoleic acids	27	273	63	497	61	86	25	151	149	100	274
	4	Extracted grain & alfalfa	27	222	67	444	56	63	14	123	117	75	239
F	1	Fat-free	7	285	62	523	60	43	14	147	138	66	214
			21	248	54	517	55	36	10	133	124	57	212
			31	231	58	448	49	31	10	129	127	55	221
	2	Fat-free & coconut oil	2	195	57	499	60	42	10	127	123	55	214
			26	299	65	458	51	49	11	134	129	71	230
	3	Fat-free & oleic & linoleic acids	27	276	58	500	51	55	12	144	136	73	241
	4	Unextr. grain & alfalfa	27	330	62	444	54	62	17	133	132	82	228

rose on the latter, to fall again when the fat-free ration was restored. The diet of extracted grain and alfalfa hay fed to goat A in the final period also caused a rise. The stearic and palmitic acids, fed to goats C and D along with either extracted or unextracted grain, produced the same results as the butter oil in causing the plasma lipids to rise, following the drop on the fat-free ration. Similarly, as shown by the data for goats E and F, these lipids were higher during the period when coconut oil was fed, and also when the mixture of linoleic and oleic was given, than at the close of the period on the basal diet. Higher values are also shown where hay and grain were fed to goats C, E, and F. A comparison of all of these data for plasma total lipids in table 2, with those for fat intake in table 1, shows that the lipid values were at their lowest on the fat-free ration and uniformly higher when fat was added either as an oil, a fatty acid or in a natural feed. It is also noted in those cases where more than one determination was made in a period that in general the response to a change in fat intake was a gradual one. This is in accord with the observations in this laboratory and elsewhere for other herbivorous animals.

The figures for cell total lipids show in general a decrease on the fat-free diet but to a much smaller degree than in the plasma. The changes occurring with the fat additions are small and show no certain trend. Clearly the character of the diet exerts its influence primarily on the lipids in the plasma rather than in the cells.

The data for the iodine numbers of the total lipids in the plasma show that these values gradually fell on the fat-free diet. This was to be expected in view of the previous observations (1, 4) with both cows and goats that a low-fat diet causes the iodine numbers of the milk fat to drop and is in accord with the recent results obtained by Hansen and Burr (12) for the rat. While the data are limited and not entirely in agreement, the changes resulting with the use of the various diets containing fat are mostly in the direction expected from the iodine number of the fat fed. An extensive study is now being made in this laboratory of the relation of the iodine numbers of the various plasma lipids to the character of the food on the one hand, and the character of the milk fat on the other. As is borne out by the data here reported, it has been found that dietary fats of widely differing iodine numbers, which produce immediate and marked differences in the iodine numbers of the milk fat, cause only small differences in the total lipids in the plasma. This means that a large number of observations must be made to obtain significant results. It is believed, however, that the data which are being accumulated will contribute to our knowledge of the source of milk fat and of the physiological changes involved.

In contrast to the data obtained for the plasma, the iodine numbers of the cell lipids, though somewhat variable, fail to reveal any changes which can be correlated with the nature of the diet. Thus it is seen that, as re-

gards state of saturation as well as amount of total lipids, the changes in the diet are reflected primarily in corresponding changes in the plasma and not in the cells.

The data for phospholipid fatty acids in the plasma show that they decreased during the fat-free period and rose with the addition of fat, thus paralleling the changes noted for the total lipids of which they made up a part. The phospholipid fatty acids are shown to occur in much larger amounts in the cells than in the plasma, as was also true, though to a lesser degree, for the total lipids. However, the changes which are shown for these acids in the cells are slight and bear no relation to the fat content of the diet, a finding which is not unexpected in view of the data for total lipids in the cells.

The data for cholesterol are of special interest in view of the mystery that surrounds the physiological significance of this compound. In the plasma the total cholesterol is shown to decrease on the fat-free diet and to rise with the addition of fat regardless of type. This finding is in accord with those for other species that the total cholesterol in the plasma tends to parallel the level of fat intake. It is noted that only a small part of this cholesterol is in the free state but that its level tends to parallel that of the total. The fact that most of the cholesterol of the plasma is combined with fatty acids and that the amount varies with the fat intake furnishes evidence for the view that cholesterol plays an active rôle in fat metabolism in lactation.

In the cells a very different picture is shown. Here the total cholesterol greatly exceeds that in the plasma. It is almost entirely present in the free state in contrast to the situation in the plasma where the major portion is present as ester. Further, this cell cholesterol remains fairly constant in amount and such changes as occur bear no relation to the changes in diet.

In general, the blood changes shown in table 2 present a picture similar in kind to that reported for non-lactating animals of other species. It thus appears that the constant withdrawal of blood lipids for the secretion of milk does not alter the essential nature of the changes in these lipids which are brought about by changes in the diet. In the previous experiments with cows (1, 3) and to a lesser degree with goats (4) the addition of fat to a low-fat diet had a positive effect upon milk and fat yield as well as upon the lipid level of the blood, suggesting the conclusion that the blood lipid level is a factor in milk yield. The very limited effect thus obtained in this experiment, except with the hay and grain, has been referred to and the possible explanations now under study have been cited. A fat-free diet which is more satisfactory as regards palatability, and perhaps also in other respects, must be devised before the full significance of results such as have been obtained in the present experiment can be determined. While the omission from the diet of ruminants of their natural roughage and the sub-

stitution of purified nutrients have obvious disadvantages, the successful use of such a controlled diet, which enables the experimenter to know the exact nature of the nutrients he is feeding and omit any one at will, should give a much more exact picture of the metabolism in milk producing animals than we have at present.

SUMMARY

The total lipids, phospholipids, free and combined cholesterol and the iodine numbers of the total lipids have been determined in the plasma and cells of the blood of lactating goats receiving in one period a nearly fat-free ration and in other periods the same ration plus certain oils and fatty acids. The fat-free diet consisted of an extracted grain mixture, regenerated cellulose, starch, molasses, extracted yeast, an A–D concentrate and a mineral mixture. The oils and acids used were butter oil, coconut oil, palmitic and stearic acids, and oleic and linoleic acids.

In the plasma the total lipids, phospholipids and total and free cholesterol dropped gradually on the fat-free diet and rose on the diets containing the fat additions irrespective of the nature of the fat fed. The iodine numbers of the total lipids in the plasma fell on the fat-free diet. With the inclusion of fat in the diet these numbers tended to change in the direction expected on the basis of the iodine number of the fat fed. In the cells the various lipid values tended to remain constant and showed no changes which could be correlated either with the nature of the diet or the changes in the plasma. The cholesterol in the cells was almost entirely in the free state while in the plasma it was present chiefly in the combined form.

In general this blood picture is similar to that reported for non-lactating animals of other species. It thus appears that the constant withdrawal of blood lipids for the secretion of milk does not alter the essential nature of the changes in these lipids which are brought about by changes in the diet.

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A STUDY OF THE PHOSPHORUS REQUIREMENT OF DAIRY CATTLE

II. PHOSPHORUS, CALCIUM AND NITROGEN METABOLISM OF DAIRY CATTLE WHEN ALFALFA FURNISHES THE PRINCIPAL SOURCE OF PROTEIN*

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The results of a study of the phosphorus requirement for growth (1) and for milk production (2) have been reported on fourteen animals which are being used in a long-time experiment. The purpose of this report is to present the results of a study of the phosphorus, calcium and nitrogen metabolism of these same animals before calving and during milk production.

Haag and coworkers (3) studied the calcium and phosphorus balances of cows producing from 9 to 19 kilograms of milk when restricted to a ration of alfalfa hay low in phosphorus (less than 0.2 per cent). The phosphorus balances were negative while the calcium balances were usually positive. When the alfalfa was supplemented with disodium phosphate the calcium and phosphorus balances were both positive. These same investigators (4) used alfalfa containing 0.153 per cent phosphorus and reported negative calcium and phosphorus balances with alfalfa alone and with alfalfa supplemented with calcium carbonate when their cows were producing from 11 to 15 kilograms of milk daily. When alfalfa was supplemented with disodium phosphate, or with bone flour, however, the calcium and phosphorus balances were positive. A calcium-phosphorus ratio in the feed of 10.5 was no more detrimental than one of 7.6.

EXPERIMENTAL

Phosphorus, calcium and nitrogen balances were determined at various times on the animals in Lots I, D3, D5, D7, D9, D11, D13, and D15, and II, D2, D4, D6, D8, D10, and D12, before calving and after the onset of milk production. The basal ration fed to the animals in Lot I before calving consisted of low phosphorus alfalfa hay (less than 0.2 per cent), corn silage and ground corn. The animals in Lot II were fed the basal ration supplemented with enough special steamed bone-meal to bring the phosphorus content up to 0.41 per cent of the dry matter. During the first lactation period a small amount of blood meal was fed due to the difficulty encoun-

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tered in getting the cows, especially those in Lot I, to consume sufficient alfalfa hay to meet their protein requirements. The blood meal furnished sufficient protein but did not materially increase the phosphorus level. The blood meal was discontinued at the end of the first lactation period and the basal ration was fed thereafter.

The amount of feed consumed during the seven day collection periods was the same as the animals had consumed prior to the metabolism periods so the question of the animals having to adapt themselves to a change in the ration was not a factor in these results.

METHOD OF PROCEDURE

The alfalfa hay was ground to facilitate mixing and weighing. Yellow corn was ground and 1 per cent iodized salt was added. All feeds were thoroughly mixed and samples were taken for chemical analysis. The calcium, phosphorus and nitrogen analyses of the feeds are shown in table 1.

TABLE 1

Average percentage composition of feeds used

FEED	CALCIUM	PHOSPHORUS	NITROGEN
Alfalfa Hay	1.468	0.161	2.188
Corn Silage	0.153	0.045	0.361
Corn	0.053	0.271	1.440
Bone Meal	28.220	13.020	2.050
Blood Meal	0.408	0.283	12.980

Shavings were used as bedding during the preliminary periods and canvas mattresses during the collection periods. The metabolism stalls were fitted with special mangers to prevent loss of feed. The cows were watered through drinking cups equipped with water-meters. The water contained 0.0083 per cent calcium. The cows were exercised in the open for 30 minutes each day during the metabolism period regardless of the weather.

The feces and urine, collected separately by means of shovels and pails by attendants, were weighed or measured respectively at the end of each 24 hour period. The excreta and milk were composited for each 7 days period and aliquot samples of each were taken for analysis. The feces, urine and milk were preserved with hydrochloric acid, thymol and formalin respectively. The methods of analysis were the same as in previous work (5).

The average daily milk yields, the average daily phosphorus, calcium and nitrogen metabolism figures are shown in tables 2 to 4. The percentage of "phosphorus used" is the algebraic sum of the "phosphorus balance" and the phosphorus in the milk. The percentages of "calcium used" and "nitrogen used" were calculated in the same manner. The date of

TABLE 2

Phosphorus balances of animals on low (D3–15) and high (D2–12) phosphorus rations

ANIMAL NO.	PERIOD	AVER. DAILY MILK	OUTGO				IN-TAKE	BAL-ANCE	USED	CA/P IN FOOD	BLOOD Ca	INORG. BLOOD P
			Feces	Urine	Milk	Total						
		kgm.	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	%		*mgm.* %	*mgm.* %
D3*	Dec. 11–18/29	–	5.52	0.12	–	5.64	11.45	5.81	50.7	3.9	11.0	6.69
D5*	Jan. 10–17/30	–	8.50	0.08	–	8.58	12.17	3.59	29.5	3.7	10.2	6.41
"	July 24–31/30	–	7.71	0.54	–	8.25	12.25	4.00	32.7	6.5	10.4	6.22
D7*	Dec. 11–18/29	–	7.03	0.09	–	7.12	11.45	4.33	37.8	3.9	10.7	5.56
D9*	Dec. 11–18/29	–	6.44	0.08	–	6.52	11.45	4.93	43.1	3.8	11.5	6.95
D11*	July 24–31/30	–	5.82	0.26	–	6.08	10.81	4.73	43.8	5.8	11.2	7.58
Average			6.84	0.20	–	7.04	11.60	4.57	39.6	4.6	10.8	6.57
D3**	Aug. 13–20/30	8.02	6.31	0.11	6.82	13.24	13.62	0.38	52.9	2.4	11.7	2.86
D5**	Nov. 10–17/30	19.47	11.51	0.08	15.57	27.16	24.08	–3.08	51.8	3.2	11.9	3.97
D7**	Aug. 13–20/30	11.43	8.52	0.13	9.37	18.02	19.06	1.04	54.6	2.6	12.1	2.86
"	Aug. 17–24/31	18.30	12.63	0.25	13.36	26.24	31.89	5.65	59.6	4.6	10.8	3.01
D9**	July 10–17/30	12.46	7.17	0.13	11.09	18.39	18.02	–0.37	59.5	2.4	11.6	2.44
"	Nov. 27–Dec. 4/30	8.51	7.82	0.07	9.11	17.00	21.55	4.55	63.4	2.0	11.8	3.98
"	Aug. 17–24/31	14.77	9.11	0.19	11.81	21.11	29.81	8.70	68.8	2.8	12.7	3.81
D11**	Mar. 27–Apr. 3/31	16.28	15.38	0.09	14.49	29.96	18.11	–11.85	14.6	3.6	12.2	3.16
D13**	Mar. 27–Apr. 3/31	18.72	9.46	0.12	16.10	25.68	18.12	–7.56	47.1	3.6	11.0	2.76
"	Aug. 17–24/31	13.17	7.41	0.18	11.45	19.04	21.98	2.94	65.5	3.8	13.7	3.33
D15**	Mar. 27–Apr. 3/31	14.17	10.01	0.15	13.18	23.34	18.12	–5.22	43.9	3.6	11.6	2.92
Average		14.12	9.58	0.14	12.03	21.75	21.30	–0.44	52.9	3.1	11.9	3.19
D2*	Dec. 31–Jan. 7/30	–	18.59	0.19	–	18.78	27.55	8.77	31.8	3.4	10.7	6.25
D4*	Dec. 31–Jan. 7/30	–	12.92	0.15	–	13.07	19.98	6.91	34.6	3.3	11.3	6.35
D6*	Jan. 10–17/30	–	14.95	0.27	–	15.22	22.35	7.13	31.9	2.9	10.1	6.25
D8*	Dec. 31–Jan. 7/30	–	18.51	0.16	–	18.67	27.55	8.88	32.2	3.4	10.1	5.84
D10*	Jan. 10–17/30	–	15.63	0.21	–	15.84	22.35	6.51	29.1	2.9	8.7	6.01
D12*	July 24–31/30	–	16.19	0.26	–	16.45	20.70	4.25	20.5	4.1	10.4	7.10
Average			16.13	0.21	–	16.34	23.41	7.07	30.0	3.3	10.2	6.30
D2**	Aug. 13–20/30	16.02	25.46	0.27	12.98	38.71	46.12	7.41	44.2	2.8	12.0	7.44
"	Nov. 27–Dec. 4/30	10.94	24.71	0.11	10.18	35.00	45.41	10.41	45.3	2.7	10.9	6.01
"	May 5–11/31	25.60	35.99	0.16	19.46	55.61	61.78	6.17	41.5	3.5	11.2	5.95
D4**	July 10–17/30	16.32	27.06	0.13	14.04	41.23	45.59	4.36	40.4	3.1	10.5	5.98
"	Aug. 17–24/31	17.25	36.72	0.45	14.32	51.49	62.22	10.73	40.3	3.6	10.4	5.37
D6**	Nov. 10–17/30	12.48	27.29	0.10	10.86	38.25	41.42	3.17	33.9	2.9	11.7	5.93
D8**	July 10–17/30	16.05	24.62	0.16	13.48	38.26	41.73	3.47	40.6	3.2	10.9	5.63
"	Nov. 27–Dec. 4/30	9.08	21.20	0.14	9.55	30.87	39.79	8.92	46.4	2.5	10.2	6.41
"	May 4–11/31	23.44	29.67	0.21	20.16	50.04	53.84	3.80	44.5	3.6	11.2	5.30
D10**	Nov. 10–17/30	18.47	27.05	0.09	14.77	41.91	42.05	0.14	35.5	2.6	12.6	5.84
D12**	Mar. 27–Apr. 3/31	13.74	21.19	0.08	12.78	34.05	35.86	1.81	40.7	2.9	9.6	5.84
Average		16.31	27.36	0.17	13.87	41.40	46.90	5.50	41.2	3.0	11.0	5.97

*Dry.

**Blood meal fed (less than 1 pound).

TABLE 3

Calcium and nitrogen balances of animals on low phosphorus ration

ANIMAL NO.	PERIOD	AVERAGE DAILY MILK	CALCIUM							NITROGEN						
			Outgo				Intake	Balance	Used	Outgo				Intake	Balance	Used
			Feces	Urine	Milk	Total				Feces	Urine	Milk	Total			
		kgm.	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	%	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	%
D3*	Dec. 11–18/29	–	28.48	0.28	–	28.76	44.13	15.37	34.8	31.81	33.04	–	64.85	94.78	29.93	31.6
D5*	Jan. 10–17/30	–	43.40	0.31	–	43.71	44.44	0.73	1.6	33.02	38.78	–	71.80	100.78	28.98	28.8
"	July 24–31/30	–	58.31	1.20	–	59.51	79.22	19.71	24.9	43.77	65.38	–	109.15	117.40	8.25	7.0
D7*	Dec. 11–18/29	–	30.62	0.18	–	30.80	44.19	13.39	30.3	33.79	36.50	–	70.29	94.78	24.49	25.8
D9*	Dec. 11–18/29	–	29.04	0.26	–	29.30	43.89	14.59	33.3	36.35	32.10	–	68.45	94.78	26.33	27.8
D11*	July 24–31/30	–	46.69	0.57	–	47.26	63.14	15.88	25.2	37.82	50.12	–	87.94	96.42	8.48	8.8
Average			39.42	0.47	–	39.89	53.17	13.28	25.0	36.09	46.25	–	78.75	99.82	21.07	21.6
D3**	Aug. 13–20/30	8.02	24.85	2.71	8.26	35.82	33.29	–2.53	17.2	–	–	–	–	–	–	–
D5**	Nov. 10–17/30	19.47	65.93	2.67	19.08	87.68	77.15	–10.53	11.1	96.40	44.01	78.26	218.67	243.72	25.04	42.4
D7**	Aug. 13–20/30	11.43	37.54	5.42	10.97	53.95	48.58	–5.35	11.6	–	–	–	–	–	–	–
"	Aug. 17–24/31	18.30	113.38	5.23	17.20	135.81	145.85	10.04	18.7	98.49	90.99	80.53	270.01	279.00	8.99	32.1
D9**	July 10–17/30	12.46	26.79	2.68	12.46	41.93	43.06	1.13	31.6	61.21	37.42	52.34	150.97	155.87	4.90	36.7
"	Nov. 27–Dec. 4/30	8.51	28.50	0.77	8.94	38.21	42.61	4.40	31.3	60.03	30.10	37.88	128.01	151.25	23.24	40.4
"	Aug. 17–24/31	14.77	61.49	0.56	13.44	75.49	82.09	6.60	24.4	79.72	75.50	63.50	218.72	231.48	12.76	32.9
D11**	Mar. 27–Apr. 3/31	16.28	60.46	2.96	17.09	80.51	65.37	–15.14	3.0	73.60	39.04	69.52	182.16	194.50	12.34	42.1
D13**	Mar. 27–Apr. 3/31	18.72	62.83	4.42	18.35	85.60	65.49	–20.11	–	72.58	41.77	76.02	190.37	194.50	4.13	41.2
"	Aug. 17–24/31	13.17	27.22	4.75	11.59	43.56	83.40	39.84	61.7	60.37	55.78	57.93	174.07	183.97	9.90	36.9
D15**	Mar. 27–Apr. 3/31	14.17	58.95	4.66	15.44	79.05	65.47	–13.58	2.8	70.23	48.20	63.05	181.48	194.50	13.02	39.1
Average		14.12	51.63	3.35	13.89	68.87	68.39	–0.48		74.74	51.42	64.34	190.49	223.50	12.70	38.2

*Dry.

**Blood meal fed (less than 1 pound).

TABLE 4

Calcium and nitrogen balances of animals on high phosphorus ration

ANIMAL NO.	PERIOD	AVERAGE DAILY MILK	CALCIUM							NITROGEN						
			Outgo				Intake	Balance	Used	Outgo				Intake	Balance	Used
			Feces	Urine	Milk	Total				Feces	Urine	Milk	Total			
		kgm.	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	%	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	*gms.*	%
D2*	Dec. 31–Jan. 7/30	–	69.24	0.49	–	69.73	93.87	24.14	25.7	44.79	47.07	–	91.86	119.39	27.53	23.1
D4*	Dec. 31–Jan. 7/30	–	45.17	0.34	–	45.51	66.50	20.99	31.6	32.34	36.64	–	68.98	92.78	23.80	25.7
D6*	Jan. 10–17/30	–	55.75	0.82	–	56.57	65.42	8.85	13.5	33.41	47.54	–	80.95	101.83	20.88	20.5
D8*	Dec. 31–Jan. 7/30	–	71.44	0.64	–	72.08	93.81	21.75	23.2	38.39	50.50	–	88.89	119.39	30.50	25.6
D10*	Jan. 10–17/30	–	57.92	0.25	–	58.17	64.54	6.37	9.9	37.17	46.52	–	83.69	101.83	18.14	17.8
D12*	July 24–31/30	–	68.01	1.27	–	69.28	84.81	15.53	18.3	40.16	55.56	–	95.72	98.36	2.64	2.7
Average		–	61.26	0.64	–	61.89	78.16	16.27	20.8	37.71	47.30	–	85.01	105.59	20.58	19.2
D2**	Aug. 13–20/30	16.02	101.38	2.12	15.22	118.72	129.29	10.57	19.9	–	–	–	–	–	–	–
"	Nov. 27–Dec. 4/30	10.94	93.83	2.18	10.61	106.62	121.81	15.19	21.2	78.97	53.33	53.29	185.59	212.98	27.39	27.9
"	May 4–11/31	25.60	166.70	1.91	27.39	196.00	214.35	18.35	21.3	118.91	66.95	106.50	292.36	354.72	62.36	47.6
D4**	July 10–17/30	16.32	121.89	0.66	15.51	138.06	141.75	3.69	13.5	117.34	39.00	76.24	232.58	249.92	17.34	37.6
"	Aug. 17–24/31	17.25	183.01	1.14	17.25	201.40	222.33	20.93	17.2	113.66	96.68	84.53	294.87	304.88	10.01	21.0
D6**	Nov. 10–17/30	12.48	95.00	1.85	13.61	110.46	118.19	7.73	18.1	92.34	66.45	55.30	215.09	213.64	–1.45	25.2
D8**	July 10–17/30	16.05	108.90	1.03	15.40	125.33	134.78	9.45	18.4	94.09	53.19	69.96	217.24	234.02	16.78	37.1
"	Nov. 27–Dec. 4/30	9.08	79.14	0.76	8.99	88.89	99.86	10.97	20.0	67.70	46.15	45.77	159.62	186.86	27.24	39.1
"	May 4–11/31	23.44	157.51	1.36	23.91	182.78	191.42	8.64	17.0	115.92	59.98	107.36	283.26	308.63	25.37	43.0
D10**	Nov. 10–17/30	18.47	86.04	1.07	19.76	106.88	109.37	2.50	20.4	89.25	41.76	73.31	204.32	237.51	33.19	44.8
D12**	Mar. 27–Apr. 3/31	13.74	94.87	1.65	14.02	110.54	103.23	–7.31	6.5	79.23	38.60	59.09	176.92	196.61	19.69	30.1
Average		16.31	117.11	1.43	16.51	135.06	144.21	9.16	17.8	96.74	56.21	73.14	226.19	249.99	23.79	35.3

*Dry.

**Blood meal fed (less than 1 pound).

metabolism period, age, weight, date of calving and the days pregnant during the metabolism periods are shown in table 5.

TABLE 5

Age, weight, and stages of lactation and gestation at the beginning of the metabolism periods

ANIMAL NO.	METABOLISM PERIOD	AGE MONTHS	WEIGHT POUNDS	DATE OF LAST CALVING	DAYS PREGNANT
		Lot I			
D3	Dec. 11–18/29	23	781		181
	Aug. 13–20/30	31	655	Mar. 10/30	none
D5	Jan. 10–17/30	24	730		31
	July 24–31/30	30	998		226
	Nov. 10–17/30	34	813	Aug. 29/30	none
D7	Dec. 11–18/29	22	764		157
	Aug. 13–20/30	30	782	Apr. 19/30	18
	Aug. 17–24/31	43	991	May 2/31	none
D9	Dec. 11–18/29	22	770		159
	July 10–17/30	29	725	Apr. 6/30	none
	Nov. 27–Dec. 4/30	34	805	Apr. 6/30	131
	Aug. 17–24/31	43	844	Apr. 18/31	14
D11	July 24–31/30	18	668		68
	Mar. 27–Apr. 3/31	27	731	Feb. 17/31	none
D13	Mar. 27–Apr. 3/31	27	753	Feb. 26/31	none
	Aug. 17–24/31	31	804	Feb. 26/31	13
D15	Mar. 27–Apr. 3/31	26	765	Feb. 26/31	none
		Lot II			
D2	Dec. 31–Jan. 7/30	24	979		217
	Aug. 13–20/30	31	948	Mar. 6/30	62
	Nov. 27–Dec. 4/30	35	1030	Mar. 6/30	168
	May 4–11/31	39	1068	Mar. 9/31	none
D4	Dec. 31–Jan. 7/30	23	780		119
	July 10–17/30	30	804	May 29/30	none
	Aug. 17–24/31	43	969	May 17/31	none
D6	Jan. 10–17/30	24	787		84
	Nov. 10–17/30	34	937	July 22/30	none
D8	Dec. 31–Jan. 7/30	23	875		186
	July 10–17/30	29	843	Apr. 2/30	17
	Nov. 27–Dec. 4/30	34	936	Apr. 2/30	157
	May 4–11/31	39	1005	Mar. 20/31	none
D10	Jan. 10–17/30	20	765		55
	Nov. 10–17/30	30	856	Aug. 11/30	none
D12	July 24–31/30	19	695		66
	Mar. 27–Apr. 3/31	27	782	Feb. 19/31	none

DISCUSSION

Phosphorus, Calcium and Nitrogen Metabolism of the Heifers Before Calving

The heifers in Lot I which received the basal ration low in phosphorus (10.81 to 12.25 grams per day) showed good calcium, nitrogen and phosphorus storage before calving. Apparently, this level of phosphorus is sufficient for maintenance, growth and gestation of heifers from 18 to 30 months of age. The inorganic blood phosphorus values would indicate the same conclusion since they remained within the normal range during most of the gestation periods and also the rate of growth was about the same as for those in Lot II. The calcium and phosphorus balances were positive for all of the animals in Lots I and II before calving, even though the average daily phosphorus intake was 11.6 grams for Lot I against 23.4 grams for Lot II. The storage of phosphorus was in favor of Lot II, due to the higher level of phosphorus intake. The animals in Lot I, however, were able to utilize phosphorus more efficiently on a ration low in this element. It is interesting to note that the calcium-phosphorus ratios in the food of the animals in the low phosphorus group varied from 3.7:1 to 6.5:1. Apparently the fairly high calcium-phosphorus ratio did not effect the efficient utilization of phosphorus under the conditions of this experiment. The calcium and phosphorus balances were slightly greater for the animals in Lot II due to the addition of bone-meal to the basal ration. The nitrogen balances did not show any outstanding characteristics although the low phosphorus group indicated a slightly better utilization of nitrogen.

Phosphorus, Calcium and Nitrogen Metabolism of Cows in Milk

The original plan was to feed alfalfa, corn silage, corn and salt as the basal ration throughout the experiment. Considerable difficulty was encountered in getting the animals in Lot I (low phosphorus ration) to consume enough alfalfa to meet their protein requirement due to the development of anorexia. A small amount of blood meal, high in protein and low in phosphorus, was fed to both lots during the first lactation period. We have mentioned previously (1) (2) that anorexia is one of the principal symptoms of phosphorus deficiency. Some trouble was encountered in running metabolism trials on the animals in Lot I due to the lack of appetite for roughage. This made it difficult to get the animals to consume a definite amount of feed for at least five days previous to and during the seven days' collection period. Animals which manifested anorexia during the preliminary trials were not used in the metabolism trials at that time. Data were discarded on those animals which manifested anorexia during the trials.

The outstanding characteristic of these metabolism trials is the efficient utilization of phosphorus by the cows in Lot I during fairly heavy milk production. With the exception of D11, the cows in Lot I utilized from 43.9

to 68.8 (average 56.7) per cent of the ingested phosphorus for milk production and body storage.

The cows in Lot I which produced more than 14 kilograms of milk per day showed negative phosphorus balances with the exception of D7 which showed a positive phosphorus balance while producing 18.3 kilograms of milk per day and D9 while producing 14.8 kilograms of milk per day. The positive phosphorus balance of D7 was probably due to the good appetite manifested by this cow after second calving, which was probably due to phosphorus storage during the four-month dry period previous to second calving. This animal had a phosphorus intake during the collection period of 31.9 grams per day which was much higher than any of the animals in Lot I with the exception of D9. D9 was changed to a higher phosphorus alfalfa hay on June 10, 1931, which resulted in an improved appetite. The improved appetite increased the phosphorus intake to 29.8 grams per day.

The animals in Lot II which received bone meal in addition to the basal ration showed positive phosphorus balances during the collection periods even with milk production as high as 25.6 kilograms per day. The phosphorus storage was decidedly in favor of the animals in Lot II although the percentage of phosphorus utilized averaged 56.7 per cent for the animals in Lot I against 41.2 per cent for the animals in Lot II. This agrees with the findings of Huffman, Robinson and Winter (5), who reported that the total intake of calcium and phosphorus has a greater significance in the utilization of these elements than has the calcium-phosphorus ratio in the food.

There was a marked difference in the calcium intake for the two lots, the average daily intake for Lot I was 68.4 grams against 144.2 grams for Lot II. This difference was due to the calcium in the bone meal and also to a greater consumption of alfalfa hay. There was a tendency for the cows on the low phosphorus ration to have negative calcium and phosphorus balances. Six of the seven cows had negative calcium balances and five had negative phosphorus balances in Lot I for one metabolism period each. An examination of the low blood phosphorus values of this Lot would indicate an inadequate amount of phosphorus in the ration.

Positive calcium and phosphorus balances were obtained for the animals in Lot II, with the exception of D12. The negative calcium balance may have been due to the fact that five weeks before the metabolism period started D12 had considerable difficulty in giving birth to a calf.

There was a tendency for the low phosphorus ration to increase the urinary excretion of calcium and to decrease the fecal calcium and phosphorus during lactation as compared to the animals in Lot II. The nitrogen balances for all animals in both lots were positive with one exception, D6. The animals in Lot I stored on the average of 12.7 grams of nitrogen per day against 23.79 grams for the animals in Lot II, but the animals in Lot I utilized their nitrogen more efficiently.

The amount of calcium and nitrogen in the rations was in excess of the needs of the animals in both lots. The amount of phosphorus was in excess of the demands of the animals in Lot II but not in Lot I. It is apparent that the supply of these elements exceeded the demands of the animals. Consequently the percentage utilized was decreased when the supply was increased above that necessary for maintenance. When the amount of phosphorus was reduced to a minimum the percentage of phosphorus utilized was increased. In the case of the calcium and nitrogen in the low phosphorus ration, the required amounts were present for maintenance but the amounts actually utilized were dependent upon the phosphorus, indicating the interdependence of these elements.

SUMMARY

1. A study was made of the phosphorus, calcium and nitrogen metabolism of heifers before calving and when in milk, on a basal ration low in phosphorus and on the basal ration supplemented with special steamed bone meal, in which alfalfa hay furnished the principal source of protein.

2. Positive phosphorus, calcium and nitrogen balances were obtained in the heifers of both lots before calving. Apparently 10.81 to 12.25 grams of phosphorus per day furnished a sufficient amount of this element for growth and pregnancy from 18 to 30 months of age.

3. Phosphorus balances during heavy milk production were usually negative on a ration of low phosphorus alfalfa hay, corn silage and corn, with or without blood meal. The phosphorus balances were positive, however, on the same ration supplemented with bone meal.

4. The cows on a low phosphorus ration utilized food phosphorus more efficiently than those on a high phosphorus ration.

5. Lack of appetite for roughage often prevented metabolism studies of the animals on the low phosphorus ration.

REFERENCES

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BY-LAWS OF THE AMERICAN DAIRY SCIENCE ASSOCIATION

ARTICLE I—MEMBERSHIP

Section 1—Membership in this Association shall consist of two kinds, active and associate.

Section 2—Any person is eligible to active membership who is formally announced by an Agricultural College or Experiment Station, or by the Bureau of Dairy Industry of the United States Department of Agriculture, or by the Canadian Department of Agriculture as an instructor, extension worker, investigator, or administrative officer connected with the dairy industry, or any person filling a position of responsibility connected with the dairy industry who has had a college or university training in technical science, or any person filling a responsible position in the dairy industry of a professional character requiring a technical knowledge of dairying of a high order.

Section 3—Any person is eligible to associate membership who is regularly enrolled in a collegiate course in a college of agriculture and who is specializing in dairying.

Section 4—Nominations for active membership shall be submitted to the Secretary-Treasurer in writing signed by the applicant and endorsed by at least one active member. In case of uncertainty regarding the eligibility of the applicant for membership the Secretary-Treasurer shall refer the application to the Board of Directors for decision. Upon receiving the approval of the Secretary-Treasurer, or the Board of Directors when the application has been referred to them for action, and the payment of membership dues, the applicant shall be enrolled as an active member of the Association.

Section 5—Associate membership of this association shall consist of those persons elected to membership in a local chapter of the American Dairy Science Association. Election to such chapter shall be governed by the rules and regulations described by the local chapter, subject only to the qualifications for associate membership as hereinbefore specified, and the approval of the head of the Department of Dairying or Dairy Husbandry in the institution where the chapter is located. Associate membership expires two years after the holder ceases to be enrolled as a student.

Section 6—The active membership dues shall be $5 a year, payable January 1st.

Section 7—Associate membership dues shall be $0.50 a year, and shall be paid annually to such officer of the chapter to which such associate mem-

ber belongs as may be provided by the chapter. Such dues shall be forwarded by the chapter to the Secretary-Treasurer of the Association.

Section 8—Any member of the Association in arrears for dues for more than one year shall cease to be a member of the Association but may be restored without the formality of reelection by payment of current dues.

ARTICLE II—OFFICERS

Section 1—The officers of the Association shall be President, Vice-President, Secretary-Treasurer, Journal Editor, and a Board of Directors.

The Vice-President shall be elected by the vote of the active membership and his term of office shall be one year beginning October 1st following his election. On the completion of his term of office as Vice-President he shall automatically become President for one year or until his successor is duly chosen. The Secretary-Treasurer and the Journal Editor shall be elected by the Board of Directors for such term of office as the Board of Directors shall prescribe.

Section 2—The Board of Directors shall consist of three members elected by the active membership, the President, Vice-President, and Secretary-Treasurer, who shall be an ex-officio member.

At the first election under this constitution as amended, one Director shall be elected for a term of one year, one for a two-year term, and a third for a three-year term; thereafter one Director shall be elected each year, whose term of office shall be three years. The terms of all Directors begin October 1st.

Section 3—The Board of Directors shall elect two members from the Association, who with the Secretary-Treasurer as ex-officio member shall constitute the Journal Management Committee, which shall be responsible to the Board of Directors. The term of service of the elected members shall be at the discretion of the Board of Directors.

Section 4—The Board of Directors may constitute and appoint such committees not provided for in the By-Laws of the Association, as they may deem proper, from their own membership or from among the active membership of the Association.

Section 5—The Board of Directors shall have the authority to fill vacancies that may occur among the officers of the Association, such appointees to serve during the remainder of the unexpired term of the office in question.

ARTICLE III—DUTIES OF OFFICERS

Section 1—The President of the Association shall preside at all meetings of the Association and meetings of the Board of Directors and shall perform such other duties as pertain to that office. The Vice-President shall perform the duties of the President in the absence of the President.

Section 2—The Secretary-Treasurer shall have custody of the books and

records of the Association, keep the minutes of all meetings of the Association and of the Board of Directors, maintain a list of members, keep the funds of the Association and make disbursements therefrom when properly authorized.

Section 3—The Journal Management Committee shall have the general supervision of the Journal. The Journal Editor, under the general supervision of this Committee, shall have direct charge of the details of the editorial and business management.

Section 4—The Board of Directors shall pass upon all applications for divisions, sections, and chapters of the Association.

Section 5—The Board of Directors shall have full control of the business of the corporation, and the title to all property and funds of the Association shall be vested in the Board of Directors. The Board of Directors shall have all the rights and powers vested in the Corporation by the laws of the District of Columbia.

ARTICLE IV—ELECTION OF OFFICERS

Section 1—On or before August first, the Secretary shall mail to each active member a blank on which he shall be entitled to express his choice for each office to be filled. This blank shall give the names of those serving in the offices to be filled for five years preceding and a report of the Committee on Elections which shall suggest the names of two members for each office to be filled. All ballots shall be counted by the Secretary and later verified by the President. In case no candidate has a majority by the first ballot, a second ballot shall be sent to the members, giving the names of the three leading candidates for each office and the number of votes received. The candidates receiving the most votes on the second ballot shall be declared elected. In case of tie on the second ballot, the decision shall be made by the Board of Directors.

ARTICLE V—MEETINGS

Section 1—Meetings of the Association shall be held at the time and place fixed by the Board of Directors but not less than one each calendar year shall be held. Notice of the time and place of meetings of the Association shall be given to all active members not less than four weeks prior to the date of meeting.

Section 2—Meetings of the Board of Directors shall be held upon call of the President, provided, however, that not less than 10 days' notice of such meeting shall be sent to each member of the Board of Directors, and provided further, that the Board of Directors shall hold a meeting for the purpose of organization within one month after the annual election.

Section 3—The quorum of any meeting of the Association shall consist of not less than ten per cent (10%) of the active membership.

ARTICLE VI—ORGANIZATION OF DIVISIONS, SECTIONS AND CHAPTERS

Section 1—Professional groups based on geographical considerations to be known as divisions of the Association and to be organized by active members of the Association may be authorized by the Board of Directors when such action shall seem expedient. The officers of the division shall be a chairman and such other officers as are provided by the division.

The divisions shall have the right to make by-laws for their own government which shall not be inconsistent with the charter and by-laws of the Association.

Membership in divisions of the Association is open only to those regularly elected active members of the Association.

Any division may raise or collect funds to be expended for its own purpose.

Section 2—Professional groups based upon specialized interests to be known as sections of the Association and to be formed by not less than ten active members may be authorized by the Board of Directors when considered for the best interests of the Association.

Such sections may elect their own officers and may make rules for their own guidance not inconsistent with the charter and by-laws of the Association.

Section 3—Local groups known as chapters may be authorized by the Board of Directors on petition from a group of members of the Association or of students qualified for associate membership according to Article 1, Section 3. The officers of the Chapter shall be a chairman and such other officers as the chapter shall provide. Membership is limited to those elected under conditions as given in Article 1, Section 3. Each chapter may make rules for its guidance not inconsistent with the charter and by-laws of the American Dairy Science Association and may raise or collect funds to be expended for its own purposes.

ARTICLE VII—JOURNAL OF DAIRY SCIENCE

Section 1—The Journal of Dairy Science, published by the Association, shall be sent to each active member, provided, however, that the Journal of Dairy Science will not be sent to the members whose dues are not paid by April 15th.

Section 2—Associate members shall have the privilege of subscribing to the Journal of Dairy Science at the rate of $2.50 per year, the subscription to be paid when the associate membership dues are paid.

ARTICLE VIII—AMENDMENTS

Section 1—These by-laws may be amended at any meeting of the Association by an affirmative vote of two-thirds of those of the active members present. In no case shall an amendment be passed by an affirmative vote of less than 10 per cent of the membership. All amendments must be referred to the Board of Directors for its recommendation prior to final action by the Association. The Board of Directors may at its discretion submit proposed amendments which have received the approval of the Board, to the active members of the Association for vote by mail. In such case, an affirmative vote of two-thirds of all voting, and which shall not be less than a majority of the active membership, shall be necessary for approval.

WATER REQUIREMENTS OF DAIRY CALVES *

F. W. ATKESON, T. R. WARREN, AND G. C. ANDERSON
Department of Dairy Husbandry, Idaho Agricultural Experiment Station, Moscow, Idaho

Calves subsist mainly on a fluid diet during the first few months of their lives. Many hand-fed calves are not offered water until they are several months of age. To obtain information on the amount of water consumed by calves, eight groups of Holstein calves under various feed conditions were observed. Both free water drunk and water consumed in feeds were recorded by weeks to obtain total water intake.

Writers on the subject of calf feeding universally stress the importance of an ample supply of fresh water, but a relatively small amount of data has been published on water consumption by calves. Henry and Morrison (4) state that "calves two to four months old, fed skimmilk, will consume from 10 pounds or less of water daily up to 20 pounds or more." Otis (7) found that at three months of age a calf will drink on the average five quarts of water daily. McCandlish (5) reported that calves drank 4 to 8 pounds of water per head daily in winter. Bowling and Ackerman (2) obtained slightly better gains in body weight and in height at withers with calves receiving no free water up to eight months of age than with calves receiving free water at will. Several investigators (1, 3, 6) have suggested that with older cattle the total water intake depended on the quantity of dry matter consumed. No report was found on the relative amounts of free water and total water consumed by calves at various ages while being fed milk.

PLAN OF EXPERIMENT

In this study water consumption by 30 Holstein-Friesian calves (excepting one Jersey-Holstein cross-bred) was recorded in connection with feeding trials. The calves were divided into groups of four each, excepting Group IV which represented only two calves. All groups were started between the months of December and March and continued for 180 days. Thus, the atmospheric temperature was relatively low when the data for early ages were taken and increased as the calves grew older.

Calves were housed in individual stalls so prepared that all feeds refused could be accounted for. Water was supplied in 14-quart pails. Check records showed evaporation to be a negligible factor. Records of consumption were summarized by weeks. Feeds were weighed and analyzed in connection with the feeding trials so that complete information was available. Hay was

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supplied *ad libitum*, but grain was limited to from 3 to 5 pounds daily, varying with the group concerned. All calves were fed similarly the first two weeks of age, being allowed to remain with the dams for approximately one day and fed whole milk until two weeks of age, at which time they were gradually changed to the experimental feed.

Group I was fed skimmilk at the rate of 12 to 16 pounds daily until six months of age. Group II was also fed skimmilk, but was limited to 12 pounds of skimmilk daily and milk feeding discontinued at four months of age. Groups III and IV were fed a solution of buttermilk curd [1] at the rate of 12 to 16 pounds per calf daily. In Group IV the solution was discontinued when the calves were four months of age, whereas in Group III the buttermilk curd solution was fed throughout the six months' period. Group V was fed a solution of Hi-Lactic milk [2] in a manner similar to that of Group III. Group VI was fed 12 pounds daily of a solution of powdered buttermilk, made up of 1.2 pounds of powder in 12 pounds of solution, until 35 days of age, when the solution was gradually replaced during one week's time by an equivalent amount of buttermilk powder, fed dry in the grain ration. Group VII was fed similarly excepting that 12 pounds of buttermilk solution contained 1.4 pounds of buttermilk powder. Group VIII was fed similarly to Group VII, except that powdered skimmilk was the experimental feed.

DISCUSSION OF RESULTS

The data have been summarized in two parts, one part dealing with water consumption of five groups of calves fed liquid milk and the other part with the water consumption of three groups of calves fed powdered milk as part of the grain ration after 35 days of age.

Average weekly water consumption per calf for the calves fed liquid milk is shown by weeks up to six months of age in table 1 and figure 1. Table 1 in addition to presenting total water subdivides water into free water, water in liquid milk, and water in hay and grain. Average pounds of dry matter consumed weekly per calf, water per pound of dry matter, average body weight, and water per 100 pounds of body weight are also presented in table 1. Since some of the calves did not receive milk to six months of age, the data presented as averages for the calves fed liquid milk represent 18 calves the first 16 weeks, 16 calves the seventeenth week, and 12 calves during the eighteenth to twenty-sixth weeks inclusive.

Water consumed in the form of hay and grain was of little importance. The maximum of seven pounds, or one pound daily, occurred in the twenty-sixth week. Milk was the primary source of water during the first few

[1] Buttermilk curd is similar in appearance to semisolid buttermilk, but contains more moisture. It is made by coagulating the buttermilk, placing coagulant in burlap sacks, and removing moisture by pressure.

[2] Hi-Lactic milk is a commercial concentrated sour skimmilk.

weeks of the calf's life, but represented a decreasing percentage of the total water intake as the calf became older because the amount of milk fed was purposely limited. When the calves were four weeks of age milk represented 99 per cent of the total water consumed; when 8 weeks, 81 per cent; 12 weeks, 61 per cent; 16 weeks, 47 per cent; 20 weeks, 41 per cent; and 26 weeks, 28 per cent. The quantity of water obtained from milk varied from 64 to 93 pounds, averaging 76 pounds per week, or 11 pounds daily per calf.

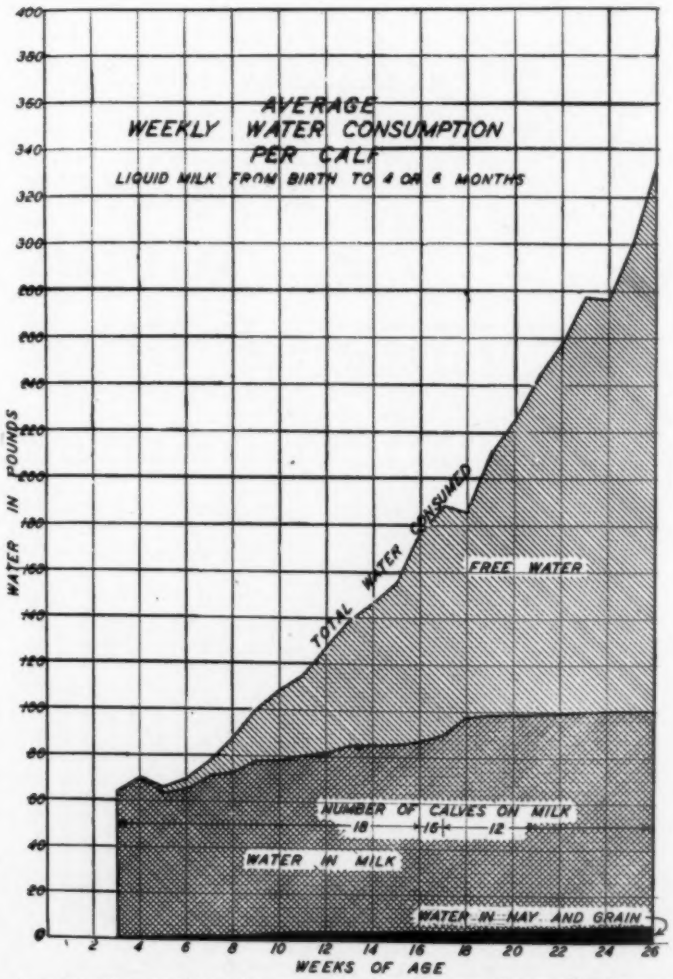

FIG. 1. AVERAGE WEEKLY WATER CONSUMPTION PER CALF FOR CALVES FED LIQUID MILK.

TABLE 1

Average weekly water consumption per calf when liquid milk was fed

AGE	FREE WATER		WATER IN MILK		WATER IN HAY AND GRAIN	TOTAL WATER		DRY MATTER	WATER PER POUND DRY MATTER	BODY WEIGHT	TOTAL WATER PER CWT. BODY WEIGHT
weeks	*lbs.*		*lbs.*		*lbs.*	*lbs.*		*lbs.*	*lbs.*	*lbs.*	*lbs.*
3	0.1		63.9		0.2	64.2		10.0	6.4	106.8	60.1
4	0.5		69.2		0.5	70.2		11.7	6.0	121.3	57.9
5	1.7		64.0		0.7	66.4		12.3	5.4	129.2	51.4
6	3.8		65.2		1.1	70.1		18.0	3.9	135.7	51.7
7	7.0		71.2		1.5	79.7		23.1	3.5	147.4	54.1
8	15.3		71.2		1.8	88.3		25.9	3.4	157.7	56.0
9	22.4		75.7		2.3	100.4		30.9	3.2	168.0	59.8
10	30.2		75.8		2.6	108.6		34.5	3.1	181.1	60.0
11	34.4		77.4		3.0	114.6		36.6	3.1	192.2	59.7
12	46.2		78.2		3.2	127.6		39.1	3.3	204.7	62.3
13	54.4		81.6		3.3	139.3		40.6	3.4	217.9	63.9
14	61.5		81.6		3.5	146.6		43.1	3.4	229.8	63.8
15	70.4		81.5		3.9	155.8		48.5	3.2	242.4	64.3
16	90.4		82.6		4.0	177.0		49.6	3.6	256.3	69.0
17	98.7	*	85.8	*	4.3	188.8	*	51.3	3.6	277.9	67.9
18	88.1	190.3	93.4	0	4.4	185.9	194.7	52.0	3.6	288.3	64.5
19	113.1	217.1	93.4	0	4.9	211.4	222.0	56.5	3.7	303.5	69.7
20	126.7	247.1	93.4	0	5.1	225.2	252.2	58.0	3.9	317.5	70.9
21	146.0	233.8	92.5	0	5.3	243.8	239.1	60.3	4.0	337.0	72.3
22	157.5	250.9	93.4	0	5.9	256.8	256.8	64.5	4.0	351.1	73.1
23	177.5	270.6	93.4	0	6.4	277.3	277.0	70.7	3.9	369.6	75.0
24	176.6	284.4	93.4	0	6.5	276.5	290.9	69.8	4.0	387.5	71.4
25	200.9	297.8	93.4	0	6.7	301.0	304.5	73.7	4.1	407.0	74.0
26	233.6	257.0	93.4	0	7.0	334.0	264.0	80.5	4.1	423.1	78.9

The data represent averages for 18 calves that received liquid milk the first 16 weeks, 16 calves that received milk during the seventeenth week, and 12 calves that received milk from the eighteenth to twenty-sixth weeks inclusive.

*This column represents the two groups (6 calves) that received no milk after the seventeenth week.

Free water drunk weekly per calf averaged 0.5 of a pound at 4 weeks of age, 15.3 pounds at 8 weeks, 46.2 at 12 weeks, 90.4 at 16 weeks, 126.7 at 20 weeks, and 233.6 at 26 weeks.

Total water intake per calf weekly averaged 70.2 pounds at 4 weeks of age, 88.3 at 8 weeks, 127.6 at 12 weeks, 177.0 at 16 weeks, 225.2 at 20 weeks, and 334.0 at 26 weeks.

These results indicate that when liquid skimmilk is fed free water is

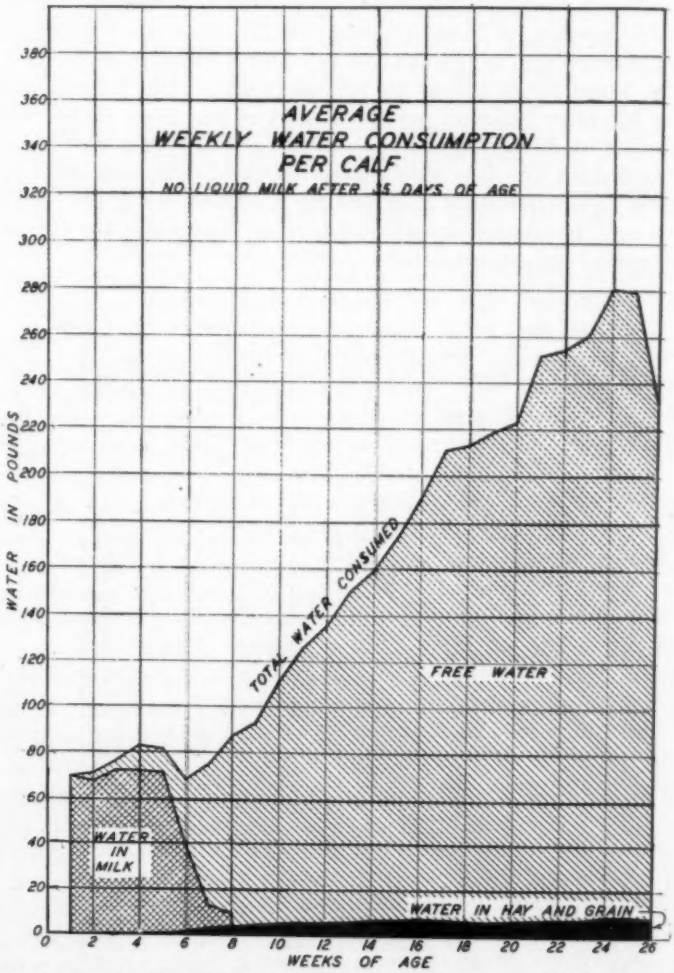

FIG. 2. AVERAGE WEEKLY WATER CONSUMPTION PER CALF FOR 12 CALVES WHEN NO LIQUID MILK WAS FED AFTER THE CALVES WERE 35 DAYS OLD. DRIED MILK WAS FED AS PART OF THE GRAIN RATION UNTIL THE CALVES WERE EITHER 4 OR 6 MONTHS OF AGE.

not important until the calf is at least 8 weeks of age since during the eighth week the calves drank an average of only 2.2 pounds of water daily. After the calves were two months old free water became increasingly more important as the calves became older, but previous to that age access to free water does not seem as essential as sometimes suggested. If the amount of milk fed daily were increased, the age when free water would be important would be extended. At what age the absence of free water would become a limiting factor cannot be determined from these experiments. The results are useful, however, in considering the normal total water requirements of calves at various ages by weeks up to six months when fed liquid milk.

Table 2 and figure 2 show the average weekly water consumption per calf for 12 calves fed milk powder as part of the grain ration, with no liquid milk after 35 days of age. In addition to total water table 2 presents water subdivided into free water, water in liquid milk, and water in hay and grain. Average pounds of dry matter consumed weekly per calf, water per pound of dry matter, average body weight, and water per 100 pounds of body weight are also presented in table 2.

TABLE 2

Average Weekly Water Consumption Per Calf When Dried Milk Was Fed in the Grain Ration

(*Liquid milk was fed until the calves were 35 days of age*)

AGE	FREE WATER	WATER IN LIQUID MILK	WATER IN HAY AND GRAIN	TOTAL WATER	DRY MATTER	WATER PER POUND DRY MATTER	BODY WEIGHT	WATER PER CWT. BODY WEIGHT
weeks	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
1		69.4		69.4	10.4	6.7	108.9	63.7
2	3.3	67.6	0.1	71.0	10.2	7.0	112.9	62.9
3	3.9	72.5	0.2	76.6	11.0	7.0	120.0	63.8
4	10.5	72.1	0.4	83.0	11.0	7.5	128.0	64.8
5	10.4	70.5	0.7	81.6	12.2	6.7	139.6	58.4
6	28.8	37.7	1.6	68.1	14.9	4.5	150.2	45.3
7	62.7	9.8	3.0	75.5	21.2	3.5	160.8	46.7
8	78.8	4.8	3.7	87.3	25.0	3.5	172.9	50.3
9	89.0		4.4	93.4	29.2	3.2	181.6	51.2
10	106.8		5.1	111.9	33.7	3.3	195.3	57.0
11	121.2		5.3	126.5	35.3	3.6	208.1	60.5
12	130.4		5.8	136.2	38.7	3.5	218.8	62.0
13	144.6		6.0	150.1	40.8	3.7	230.7	65.1
14	153.5		6.7	160.2	45.6	3.5	245.0	65.1
15	167.4		6.8	174.2	46.8	3.7	260.3	66.7
16	189.6		7.3	196.5	51.5	3.8	272.0	72.2
17	203.9		7.0	210.9	52.8	4.0	285.4	73.9
18	206.4		6.7	213.1	50.0	4.3	296.7	71.8
19	213.0		6.1	219.1	46.3	4.7	306.8	71.4
20	215.1		6.9	222.0	51.4	4.3	321.8	69.0
21	244.6		7.1	251.7	53.6	4.7	334.3	75.3
22	246.5		7.8	254.3	59.5	4.3	344.6	73.8
23	252.9		7.8	260.7	59.8	4.4	359.4	72.5
24	271.7		8.7	280.4	66.5	4.2	373.7	75.0
25	270.4		8.7	279.1	67.1	4.2	388.2	71.9
26	223.9		8.0	231.9	62.2	3.7	399.7	58.0

The data represent averages for 12 calves.

Little free water was consumed while liquid milk was fed, as might be expected from figure 1, since these calves were taken off liquid milk before free water consumption became important. Change from liquid milk to the dry grain mixture caused a temporary reduction in total water consumption, due to the fact that the calves did not adjust themselves to the change immediately. After these calves had been on the dry grain mixture for two weeks their water consumption equalled that of the liquid milk group and continued to increase as the calves grew older. Except for the adjustment period, total water intake in these groups was approximately the same as for the groups fed liquid skimmilk. Enough additional free water was consumed to compensate for the water normally consumed in liquid milk.

Further evidence that free water consumption depends on the character of the ration is found in table 1 for the two groups of calves which received no milk after the seventeenth week. Enough more free water was drunk to make the total water intake about the same as for those calves receiving milk up to six months of age.

These facts indicate that the total water requirements of calves at the various ages are rather definite, regardless of the form in which the water is consumed.

These results are in accord with the report of Atkeson and Warren (1) on the total water consumption of dairy cows. They found that total water intake was rather constant, other conditions being controlled, regardless of whether or not succulent feed was fed, the adjustment being made by the cows through more or less free water drunk.

Figure 3 shows the relationships of total water intake, body weight, and dry matter consumed for the calves receiving liquid milk (table 1). Considering the fact that the season of year when the calves were born resulted in an increase in temperature as the calves became older, the relationship between total water intake and body weight and dry matter consumed is quite marked. During the first 10 weeks when the calves' diet was principally milk, the relationship between dry matter and water was not so close. The relationship between dry matter consumed and body weight was quite constant from the tenth to the twenty-sixth week. This is of particular interest since hay was fed at will and although an upper limit was established for grain the amount fed varied with the condition of the individual calves. Quite similar results were obtained with the calves fed no liquid milk after 35 days of age (table 2). Whether total water intake depends on body weight or on dry matter consumed or both cannot be determined from these results because of the constant relationship between body weight and dry matter consumed. Recent work by Atkeson and Warren (1) indicates that with non-lactating dairy cows dry matter consumption seems to govern total water intake.

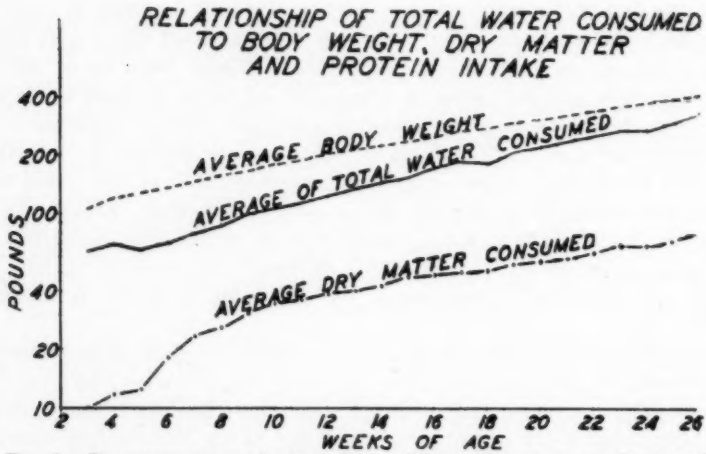

FIG. 3. RELATIONSHIP OF AVERAGE TOTAL WATER CONSUMED TO AVERAGE BODY WEIGHT AND TO AVERAGE DRY MATTER CONSUMED FOR THE CALVES FED LIQUID MILK UP TO 4 OR 6 MONTHS. DATA FROM TABLES 1 AND 2 ARE CHARTED SEMI-LOGARITHMICALLY TO FACILITATE COMPARISONS.

CONCLUSIONS

The total water requirement of dairy calves seems to be rather definite at various ages up to six months. Free water does not seem important for calves receiving liquid milk until they are at least eight weeks of age, but becomes increasingly more important as the calves become older. When liquid milk is removed from the diet, calves tend to drink enough more free water to compensate for the water in the milk, thereby keeping the total water intake about the same as for calves fed liquid milk. The relationship between total water intake, body weight, and dry matter consumption was quite constant, especially after the tenth week.

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INFLUENCE OF MASTITIS ON THE CURD TENSION OF MILK*

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Considerable interest has developed in soft curd milk since Hill (5) developed a test for quantitatively measuring the difference in curd character of milk from individual cows and indicated the value of soft curd milk for infant feeding. Hill (7) calls any milk with a curd tension of less than 30 grams "soft curd milk" and all above 30 grams "hard curd milk." This standard has been adopted by various health departments which are making soft curd determinations.

Hill (6, 7, 8) and Espe and Dye (4) have found that soft curd milk is more easily digested than hard curd milk and that cow's milk with the soft curd character is an excellent infant food. Weisberg, Johnson, and McCollum (10) report that the concentration of casein is the major factor in determining the curd character of cow's milk and that soft curd milk contains less calcium and phosphorus than hard curd milk, but the ratio of calcium to phosphorus is substantially the same regardless of the curd character.

Allemann and Schmid (1), Buckley (2), and Hill (6, 7, 8) have established that curd tension varies with individual cows, stage of lactation period, and breeds.

Although both heat and homogenization, according to Hill (8), reduce the curd tension of milk, the prevailing method of producing soft curd milk is to select milk from cows naturally producing it. Observation in the University of Idaho dairy herd and in commercial dairy herds indicated some relationship between mastitis and the production of soft curd milk.

Mastitis is one of the most prevalent diseases of dairy cattle. Most of the authorities on mastitis are agreed that a large majority of the cases are caused by a streptococcic infection. In some instances the organism causing mastitis, if of human origin, has been responsible for epidemics of septic sore throat. If there is any relationship between mastitis and the production of soft curd milk by individual cows, it is obvious that greater precautions must be taken in the production of this type of milk.

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PROCEDURE

Milk used in this investigation came from individual cows of the University of Idaho dairy herd, composed of Holsteins and Jerseys. This herd is under constant veterinary supervision and is federally accredited for tuberculosis and state accredited for Bang's abortion disease.

Part I

A composite sample was taken from each cow's milk, after discarding the fore milk, and the following determinations made:

1. Bacterial count by plate method according to "Standard Methods of Milk Analysis."
2. Bacterial count by plate method, using nutrient agar to which had been added one per cent of dextrose and five per cent of defibrinated horse blood.
3. Leucocyte count, using the Prescott and Breed technic for direct count.
4. Curd tension, using the procedure and equipment recommended by Hill (7).
5. Streptococci or staphylococci grouping.

Part II

Samples of milk were taken from each individual quarter of each of the 12 cows used. A special milk pail with four separate compartments was used. Milk from each quarter was weighed and sampled. After sampling, the milk from each quarter was thoroughly mixed with the milk from the other three quarters and a composite sample taken as a check against the individual quarters. The same tests were made as in Part I, and, in addition, the black cloth test for detecting the presence of white flakes in the milk.

A physical examination of the udders of all cows was made the same day samples were taken to determine physical symptoms indicative of mastitis.

All cases of mastitis presented in this paper were chronic in nature.

PRESENTATION OF DATA

Part I

Table 1 presents the results on 46 composite samples of milk from 26 individual Holsteins and 20 individual Jerseys. Results show that with the occurrence of mastitis there was an increase in bacterial counts on both plain and blood agar, an increase in leucocyte counts, and a decrease in curd tension.

TABLE 1

Influence of mastitis on bacterial count, leucocyte count, and curd tension of milk
(Composite Samples)

NO. OF COW	BACTERIA PER CC.		LEUCOCYTES PER CC.	CURD TENSION
	Plain agar	Blood agar		
		Normal Cows		
64	100	4,200	93,000	53.0
74	700	9,200	93,000	26.0
2X	400	1,000	70,000	47.5
4X	300	200	23,000	26.0
5X	400	400	46,000	33.5
8X	300	200	46,000	37.5
9X	500	400	46,000	52.5
19X	100	100	23,000	37.5
22X	500	100	46,000	40.0
23X	700	400	46,000	30.0
25X	50	300	93,000	50.0
26X	200	400	23,000	28.5
27X	1,000	800	11,500	23.5
28X	50	100	11,500	30.0
155	3,200	2,000	23,000	94.0
156	300	100	46,000	50.0
157	1,600	3,200	132,000	62.0
160	800	300	23,000	70.0
165	50	50	46,000	60.0
168	300	400	46,000	52.5
169	50	100	23,000	82.0
170	200	100	23,000	84.5
172	1,400	1,800	46,000	74.0
173	200	0	132,000	80.0
175	500	50	23,000	70.5
176	100	100	46,000	72.0
178	800	100	23,000	55.0
181	2,700	2,100	11,500	42.5
198	0	100	11,500	55.0
		Streptococcic Infection		
55	300	500	300,000	28.0
65	7,000	6,200	8,800,000	24.0
67	650	2,000	308,000	32.5
83	10,000	13,000	2,040,000	15.0
78	100	225,000	2,420,000	14.0
98	100	42,000	934,000	23.0
18X	8,000	10,600	880,000	20.0
24X	75,000	240,000	140,000	19.0
52	8,400	24,000	1,868,000	10.0
151	10,200	76,000	8,000,000	62.0
164	600	500	640,000	40.0
167	200	4,200	1,760,000	23.0
		Staphylococcic Infection		
70	1,800	5,400	46,000	36.0
80	4,200	300	280,000	67.5
13X	3,000	15,000	858,000	37.5
150	1,200	8,000	2,040,000	37.5
159	1,500	1,750	640,000	87.0

Note: Cows with numbers below 100 are Holsteins and cows with numbers above 100 are Jerseys.

Of the 15 cows that produced soft curd milk, according to Hill's classification, 9, or 60 per cent, had chronic mastitis, all caused by a streptococcic infection. Each of these 9 cows produced milk having a leucocyte count in excess of 100,000, which agrees with Cherrington *et al.* (3), and in 8 of 9 instances, particularly on blood agar, a relatively high bacterial count.

Seventeen of the 46 cows had chronic mastitis. Twelve of the 17 cases of mastitis were caused by streptococcic infection and 5 by staphylococcic infection. The curd tension of the milk from cows with streptococcic infection ranged from 10 to 62 grams, with an average of 26.0 grams. Nine of these 12 cows produced milk with a curd tension below 30 grams. The curd tensions of milk from cows with staphylococcic infection were all above 30 grams and ranged from 36 to 87 grams, with an average of 53.0 grams. This would indicate that mastitis caused by a streptococcic infection lowers the curd tension more than mastitis caused by a staphylococcic infection.

Part II

When the relationship between mastitis and curd tension became apparent, it was thought advisable to continue the work under more carefully controlled conditions. All the milk from individual quarters was used and composite samples were not taken except as checks. Two preliminary trials were run, followed by a third trial in which detailed information was secured.

Table 2 presents the data of the third trial on individual quarters of 12 cows, 6 Holsteins and 6 Jerseys. Two cows of each breed were normal, healthy cows; and four of each breed had chronic mastitis in one or more quarters.

In every instance milk from quarters having mastitis showed a higher leucocyte count than milk from normal quarters and in 7 out of 9 instances a lower curd tension. Every quarter having a streptococcic infection gave milk with a curd tension of 30 grams or below, while quarters having a staphylococcic infection gave milk with a high curd tension.

The curd tension of milk from individual quarters of normal cows was comparatively uniform. However, when one or more quarters of cows having mastitis had a streptococcic infection, the curd tension of these quarters was lower than that for normal quarters.

The black cloth test was very effective in determining mastitis caused by a streptococcic infection. Streptococcic infection usually caused flaky milk, whereas staphylococcic infection did not.

Data in table 2 do not seem to show any correlation between the development of fibrous tissue in a quarter and low curd tension of milk from that quarter. Five quarters showed a slight fibrous development, only one of which showed lower curd tension than the average from the cows involved. Six quarters showed moderate to extensive fibrous tissue development, three

TABLE 2

Influence of mastitis on bacterial count, leucocyte count, and curd tension of milk (Individual Quarters)

NO. OF COW	QUARTER	BACTERIA PER CC.		LEUCOCYTES PER CC.	BLACK CLOTH TEST	TYPE OF INFECTION	VETERINARY EXAMINATION OF UDDER	CURD TENSION
		Plain agar	Blood agar					
				Normal Cows				
	R.F.	9,000	7,800	23,000	–		Very meaty	26.0
	R.R.	100	500	23,000	–		Very meaty	26.0
8X	L.R.	600	300	23,000	–		Very meaty	26.0
	L.F.	400	1,100	46,000	–		Meaty	22.0
Composite		800	400	46,000	–			22.0
	R.F.	900	500	23,000	–		Meaty, extra heavy, sl. fibrosa	33.0
	R.R.	2,200	900	23,000	–		Meaty	32.0
64	L.R.	800	2,600	23,000	–		Meaty	30.0
	L.F.	300	600	46,000	–		Meaty	32.0
Composite		900	1,300	23,000	–			33.0
	R.F.	3,500	2,600	46,000	–		Normal	60.0
	R.R.	7,600	2,400	23,000	–		Normal	60.0
165	L.R.	17,600	10,300	23,000	–		Left side light	61.0
	L.F.	7,300	4,800	23,000	–		Left side light	70.0
Composite		8,000	4,300	46,000	–			63.5
	R.F.	1,600	800	23,000	–		Normal	111.0
	R.R.	3,300	1,800	23,000	–		Normal	122.5
169	L.R.	4,000	1,700	23,000	–		Normal	93.5
	L.F.	4,800	1,900	23,000	–		Normal	98.5
Composite		3,600	1,600	23,000	–			95.0
				Streptococcic Infection				
	R.F.	5,200	5,600	960,000	+	Streptococcic	Udder very meaty, Fibrosa 1	19.0
	R.R.	5,000	9,800	184,000	+	Streptococcic	Udder very meaty	23.0
55	L.R.	9,600	10,300	92,000	–		Udder very meaty, Fibrosa 1	28.5
	L.F.	11,400	13,200	46,000	–		Udder very meaty	26.0
Composite		11,600	13,200	460,000	+	Streptococcic		23.5
	R.F.	1,400	16,200	230,000	–		Meaty, spider	27.0
	R.R.	2,400	23,000	460,000	+	Streptococcic	Meaty, spider	25.0
24X	L.R.	300,000	275,000	322,000	+	Streptococcic	Meaty, spider	25.0
	L.F.	7,200	10,000	138,000	–		Meaty, spider	24.0
Composite		36,000	43,000	322,000	+	Streptococcic		24.0

TABLE 2—(*Continued*)

NO. OF COW	QUARTER	BACTERIA PER CC.		LEUCOCYTES PER CC.	BLACK CLOTH TEST	TYPE OF INFECTION	VETERINARY EXAMINATION OF UDDER	CURD TENSION
		Plain agar	Blood agar					
	R.F.	10,000	16,000	312,000	+	Streptococcic	Meaty	30.0
	R.R.	10,400	12,400	276,000	–		Meaty	35.0
67	L.R.	21,000	20,000	920,000	+	Streptococcic	Meaty	20.0
	L.F.	8,000	10,200	276,000	–		Meaty	30.0
Composite		14,400	17,300	322,000	+	Streptococcic		30.0
	R.F.	100	1,000	1,186,000	–	Streptococcic	Udder meaty	28.0
	R.R.	100	200	467,000	–		Udder meaty	54.0
167	L.R.	100	100	92,000	–		Udder meaty	56.0
	L.F.	0	100	186,000	–		Udder meaty	46.0
Composite		200	300	794,000	–	Streptococcic		49.0
	R.F.	1,000	3,400	966,000	–		Fibrosa 1	75.0
	R.R.	8,000	9,700	1,610,000	–		Fibrosa 2	55.0
151	L.R.	18,200	33,000	6,900,000	+	Streptococcic	Fibrosa 3	25.0
	L.F.	3,200	4,000	96,000	–		Fibrosa 3	67.5
Composite		3,600	3,900	736,000	+	Streptococcic		67.5
				Staphylococcic Infection				
	R.F.	800	2,100	276,000	–	Staphylococcic	Normal	47.5
	R.R.	6,200	9,000	23,000	–		Normal	50.0
70	L.R.	1,900	1,000	23,000	–		Slight fibrosa, light quarter	47.5
	L.F.	1,300	1,000	46,000	–		Light quarter	40.0
Composite		2,300	3,100	92,000	–	Staphylococcic		47.5
	R.F.	8,000	9,200	46,000	–		Shrunken	61.0
	R.R.	110,000	100,000	46,000	–		Normal	72.5
150	L.R.	5,200	6,000	3,036,000	–	Staphylococcic	Fibrosa 3	47.0
	L.F.	12,000	14,000	92,000	–		Fibrosa 1	74.0
Composite		16,000	19,500	276,000	–	Staphylococcic		74.0
	R.F.	0	200	327,000	–	Staphylococcic	Normal	111.0
	R.R.	100	400	187,000	–	Staphylococcic	Fibrosa 2	110.0
159	L.R.	1,400	1,700	233,000	–	Staphylococcic	Fibrosa 3	98.0
	L.F.	400	600	140,000	–	Staphylococcic	Normal	95.0
Composite		600	700	280,000	–	Staphylococcic		106.0

of which showed a curd tension lower than the composite sample from the cow involved. Meaty or coarse udders showed no more tendency to low curd tension milk than fine-textured udders.

DISCUSSION OF RESULTS

Soft curd milk is, in general, produced only by the more modern and better equipped dairies. These dairies have constant and competent veterinary inspection and supervision. The practice is to immediately remove from the herd any cow contracting mastitis. Under these conditions there is little likelihood of any soft curd milk being produced by cows having mastitis. However, due to competition some dairies not so efficiently managed and without regular veterinary service may attempt to produce soft curd milk. Without regular veterinary service the production of soft curd milk holds much danger since it is frequently difficult to determine the presence of mastitis. Data presented in this paper indicate that if mastitis is caused by a streptococcic infection the milk will invariably have a lower curd tension than milk from either normal quarters or normal cows. The streptococcic infection usually lowers the curd tension sufficiently for the milk to be called "soft curd milk." However, if the mastitis is caused by a staphylococcic infection there does not seem to be any appreciable effect on the curd tension. In this work the black cloth test was very successful in indicating mastitis when caused by a streptococcic infection but not when caused by a staphylococcic infection.

Udall and Johnson (9) have stated that a physical examination of the udder for excessive fibrous tissue immediately following milking is a reasonably satisfactory method of detecting mastitis. Since it appears that mastitis usually lowers the curd tension of milk, there might logically be expected some relationship between the development of fibrous tissue in a quarter and low curd tension of the milk from that quarter. Data presented in table 2 do not substantiate that hypothesis.

It might appear that undue emphasis has been placed on the possibility of soft curd milk's being caused by mastitis. It is true that in certified dairies this possibility is remote, but in most herds mastitis occurs frequently. It is apparent from the data presented that chronic mastitis caused by a streptococcic infection might cause milk from individual cows to be of a soft curd character. In fact, the possibility is so great that it is recommended that no cow be used for the production of soft curd milk unless it is absolutely certain that she is at all times free from mastitis as determined by both a physical and bacteriological examination.

SUMMARY

1. Mastitis caused by a streptococcic infection invariably lowered the curd tension of milk.

2. Mastitis caused by a staphylococcic infection apparently had no appreciable influence on the curd tension of milk.

3. The black cloth test successfully detected mastitis caused by a streptococcic infection, but not that caused by a staphylococcic infection.

4. There was no correlation between the development of fibrous tissue in the udder and the curd tension of the milk in the cases studied.

Since this paper was accepted for publication a similar paper entitled "Soft Curd Milk and Mastitis," by R. C. Welch and F. J. Doan has been published in the Milk Plant Monthly, vol. 22, No. 11, p. 30–36, Nov. 1933. The latter was contributed from the Pennsylvania Agricultural Experiment Station as Technical Paper No. 608, approved for publication Oct. 7, 1933.

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THE INFLUENCE OF TYPE OF RATION AND PLANE OF PRODUCTION ON WATER CONSUMPTION OF DAIRY COWS[1]

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INTRODUCTION

Water is important in the nutrition of dairy cows because it represents 87 per cent of the composition of milk and over 50 per cent of the cow's body. As the plane of production rises water increases in importance. Considerable data have been presented on the use of water by dairy cows; but none of the results have applied to cows milking over 60 pounds daily, with the exception of one cow milking about 100 pounds, reported by Eckles (5). Cows producing less than 30 pounds daily were used in most of the investigations. Although several of the factors affecting water consumption have been studied, the data presented in many cases could not be used to determine the water requirements of cows under conditions differing from those of the particular experiment.

The two factors studied in this experiment were: first, the influence of adding a succulent feed to the ration on water consumption; and second, the influence of plane of production on water consumption. Additional data are furnished on the water requirements of very high producing cows. An attempt has been made to present the findings in such a manner that they may be used within limits to estimate the water requirements of other cows. Data on the number of times cows drink and the quantity consumed during night and day are also reported.

REVIEW OF LITERATURE

Fairbanks and Smith (6) in discussing the importance of plenty of fresh water make this statement: "A large dairy cow in milk will drink from 150 to 300 pounds of water in a day, while the same cow when dry will not consume over 50 to 70 pounds of water." Savage and Maynard (17) state, "A large, heavy milking cow will drink 8 to 15 gallons a day, depending on her feed." Morrison (8) in reviewing the use of water by dairy cows states, "Cows in milk require on the average about 100 pounds, or 12.5 gallons, of water a head daily, and high producing cows even more." Perkins and Monroe (13) found that cows on a low protein ration drank 62 pounds of water when producing about 30 pounds of milk.

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Fuller (7) states that ". . . general evidence indicates that the amount of water required by a cow is influenced mainly by the amount of milk she is giving, character of the feed, and temperature of the barn air. . . . More water will be drunk when cows are fed a ration rich in protein than when on a low protein ration."

Ritzman and Benedict (15) in studying the metabolism of milch cows state: "Insensible perspiration is the safety valve by which the animal eliminates excess heat during high pressure metabolism. Daily changes in amount of feed consumed, in humidity and environmental temperatures invariably reacted on the insensible perspiration without a corresponding change in milk flow." These investigators also found (16) that the metabolic rate of sheep during lactation was uniformly higher than at any other time of the year at which it was measured.

Cannon, Hansen, and O'Neal (2) compared water consumption of cows during winter months when watered outside twice daily and when watered inside at will. Alfalfa hay, grain mixture, and silage were fed; and the average milk production for 12 cows over a period of about four months was approximately 26 pounds. The maximum average production for a 28-day period was 42 pounds on one cow. When watered inside, the 12 cows drank an average of 3.5 pounds of water per pound of milk produced; while outside the ratio was 3.1 pounds of water per pound of milk. Averaging both inside and outside watering the ratio of milk to water was 1 to 3.3. They report that apparently water temperature did not affect water consumption as much as atmospheric temperature.

Fuller (7) found that 16 cows, averaging 1167 pounds in weight and producing 27.8 pounds of milk, drank 121.7 pounds of water daily, a free water to milk ratio of 4.4 to 1. The trial was conducted in January with cows receiving hay, grain, and silage. The maximum was 233¾ pounds of free water drunk by a 1340-pound Holstein cow producing 45.6 pounds of milk, or approximately 5 pounds of water per one pound of milk. He states, "The consumption of water has commonly been considered as being determined largely by the amount of food eaten, more specifically the dry matter. Kellner[4] assumed about 4 kilograms of water per kilogram dry matter."

Ritzman and Benedict (14) found that with steers, "The water intake shows an exceedingly close relationship to the amount of dry matter ingested . . . the ratio of water to dry matter is essentially the same (*i.e.*, 3.0 to 3.4 kilograms of water per kgs. dry matter) on all three feed levels." Steers on high protein feed drank 26 per cent more water than steers on low protein feed.

Larsen, Hungerford, and Bailey (9) reported that cows averaging less than 18 pounds of milk and receiving silage, hay, and grain consumed water

[4] Original reference not available.

at the ratio of 4.3 pounds of free water and 5.7 pounds of total water (including water in feeds) per pound of milk produced. The ratio of free water drunk to each pound of dry matter consumed was 3 to 1.

Eckles (4) reported that two Jersey cows, three months in milk, on full ration produced an average of 26.8 and 13.3 pounds of milk and drank 77.3 and 40.3 pounds of water, or 2.9 and 3.0 pounds of water per pound of milk produced. The same two cows, dry and farrow, on a maintenance ration drank 14.7 and 12.8 pounds of free water. Eckles (5) also reports seven days' production on a cow that averaged 102.9 pounds of milk. She drank an average of 250 pounds of water per day, making a ratio of free water to milk of 2.43 to 1. The ratio of total water to milk was 2.54 to 1 and the ratio to dry matter ingested was 7.46 to 1.

As early as 1888 Armsby and Caldwell (1), in conducting a digestion trial on one cow, reported that 60.9 pounds of water were drunk when the cow was fed 79 pounds of green grass only and 106.5 pounds of water when the same quantity of grass was fed dried. Milk production averaged 26 and 25 pounds for the two periods, making a ratio of 2.3 pounds of water to one pound of milk when green grass was fed and 4.2 to one when dried grass was fed.

McCandlish and Gaessler (10) found that five cows averaging 16 pounds of milk daily and being fed soiling crops drank an average of 3.5 pounds of water per pound of milk, but the water in the feeds brought the total water consumption up to 5.33 pounds per pound of milk and 5.45 pounds per pound of dry matter consumed. They state, "There was also a quite regular relationship between water consumption and dry matter consumed." The results were obtained in midsummer.

As evidence of the effect of the character of ration on free water consumption, Morrow and Ackerman (12) reported that during a 28-day period two cows, when receiving mangels, consumed an average of 40.39 and 73.49 pounds of water daily; but when corn silage replaced the mangels they consumed an average of 75.08 and 101.0 pounds of water daily in a similar period.

Collier (3) in three years' trials with 23 cows, representing six breeds, found that an average of 4.68 pounds of free water was drunk per pound of milk. Four Holsteins averaged 4.43 pounds to 1 of milk. With reference to the influence of the character of the ration on the amount of water consumed, he states, "When ensilage, roots, green forage, or other food containing much water is introduced in the daily ration, the amount of water drunk is, as a rule, diminished by such amount as such food contains."

With reference to the number of times cows drink, Cannon, Hansen, and O'Neal (2) state: "Cows watered with bowls drank an average of about 10 times in each 24 hours. Approximately two-thirds of the water was con-

sumed in the daytime, that is between 5 a.m. and 5 p.m., and the other third at night."

Woodward and McNulty (18) found that more water was drunk in the daytime than during the night, but time of feeding hay had some effect. "During 15 days when hay was fed at 4:30 p.m., 73.1 per cent of the water was drunk between 7 a.m. and 7 p.m. During the 15 days when hay was fed at 7:30 p.m. only 58 per cent of the water was drunk during the day."

PROCEDURE

Seven registered Holstein cows that gave promise of high production during the next lactation and that were due to freshen within 60 days of each other (between February and April) were selected from the University of Idaho herd. Each cow was placed under observation for four periods of three days each, as follows:

1. While dry, and receiving no succulence (alfalfa hay and a grain mixture).
2. While dry, and receiving succulence (alfalfa hay and grain mixture plus corn silage or beet pulp).
3. During high production (about three weeks after freshening, approximately peak production), and receiving succulence (alfalfa hay, grain mixture, and silage).
4. During medium production (7 to 9 months after freshening), and receiving succulence (alfalfa hay, grain mixture, and silage).

Periods of three days were selected in an attempt to get representative data under the different conditions and at the same time have a period short enough to minimize the influence of other factors, such as changes in body weight, milk production, barn temperature, humidity, etc. In studying the influence of adding succulent feeds to the ration on the daily water consumption, the first two experimental periods were purposely conducted when the cows were dry to eliminate the influence of milk production. Since it was possible to conduct these two periods within a week of each other, the influence of body weight and climatic conditions was minimized.

A Neptune Trident automatic self-recording water meter was connected to a Louden drinking cup in a box-stall (11×11 feet). The meter recorded on a circular chart by 12-hour periods the amount of water and the exact time of day when consumed. All the cows used were accustomed to box-stall care and to drinking from Louden drinking cups. The meter was located about 15 feet from the cup and obscured from the cow's view.

While dry the cows were on full feed to fit them for the next lactation. After freshening all the cows were on official test and were milked four times daily. As indicated in table 1, relatively large quantities of feed were consumed. While in milk the cows were fed grain in the ratio of about one pound of grain to four pounds of milk. The grain mixture contained ap-

TABLE 1

Average milk production, and feed and water consumption by seven cows during four periods

Period	1			2			3			4		
Production	None			None			High			Medium		
Type of Feed	Dry			Succulent			Succulent			Succulent		
	Feed	Dry Matter	Water	Feed	Dry Matter	Water	Feed	Dry Matter	Water	Feed	Dry Matter	Water
	lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Alfalfa hay	13.2	11.3	1.9	12.8	10.9	1.9	21.2	18.6	2.6	20.5	18.4	2.1
Grain mix	17.4	15.2	2.2	15.4	13.4	2.0	20.0	17.6	2.4	7.8	6.9	0.9
Molasses solution	1.7	0.2	1.5	1.7	0.2	1.5	8.7	1.3	7.4	.....	.....	.....
Succulence (silage or beet pulp)	.....	.....	.....	29.6	5.9	23.7	33.9	6.3	27.6	32.4	4.8	27.6
Free water	.....	.....	93.1	.....	.....	73.5	.....	.....	191.4	.....	.....	109.7
Total	.....	26.7	98.7	.....	30.4	102.6	.....	43.8	231.4	.....	30.1	140.3
Body weight		1637			1643			1512			1512	
Milk produced		.....			.....			82.4			30.2	
Water in milk		.....			.....			71.7			26.3	
Free water per lb. of milk		.....			.....			2.3			3.6	
Total water per lb. of milk		.....			.....			2.8			5.2	
Production water* per lb. of milk		.....			.....			1.6			1.3	
Total water per lb. of dry matter		3.7			3.4			5.3			4.7	
Total water less water in milk, per lb. of dry matter		.....			.....			3.7			3.7	
Total water per cwt. of body weight		6.0			6.2			15.3			9.3	
Total water less water in milk, per cwt. of body weight		.....			.....			10.5			6.2	

* Called production water only as a convenient term. Obtained by subtracting from total water the 100 pounds of water consumed during the dry periods. This 100 pounds might be considered as used for purposes other than in milk.

proximately 15 per cent digestible crude protein. Salt was fed as one per cent of the grain ration; and, in addition, free access to salt in a box was provided. Diluted molasses was poured over the grain during Period 3 only, except that cow No. 78 received it in Periods 1 and 2 also.

Records were kept on body weight, milk production, feed consumption, moisture content of feeds, quantity and time of water consumption, temperature of water, and temperature of barn. During the three trials the water temperature was quite constant, varying from 50° to 54° F. The barn temperature hovered around 50° F., with a variation above and below not to exceed 10 degrees. The water meter recorded in tenths of a gallon and was checked for accuracy before each trial. The charts were changed at 7 a.m. and 7 p.m.

RESULTS

Effect of Adding Succulence to the Ration on Total Water Consumption

Practically the same amount of total water was consumed with and without succulence in the ration. Less free water was consumed when succulence was added to the ration; but the water intake through the succulence about equaled the reduction in free water, making the total water approximately the same (Table 1). Fig. 1, Period 1, presents the average water consumption of the seven individual cows and the group average during the three days when the cows were dry and received no succulence in the ration. Period 2 of the same figure presents similar data when the cows were likewise dry, but succulence had been added to the ration. For comparison with water consumption the average body weights and the average dry matter consumed during the three-day periods are also presented in Fig. 1, Periods 1 and 2. Without succulence the cows consumed daily an average of 93.1 pounds of free water, which together with water in the feed made 98.7 pounds of total water; while with succulence 73.5 pounds of free water were consumed, which added to water in the feed made a total of 102.6 pounds. When receiving succulence the cows consumed slightly more dry matter. Total water per pound of dry matter consumed averaged 3.7 pounds when no succulence was fed and 3.4 pounds when succulence was added, the difference being due to more dry matter as the result of the addition of succulent feed. The average body weights of the cows were practically the same on both trials, being 1637 pounds without succulence and 1643 with succulence. Since body weights and total water intake were about the same for both periods the total water consumed per hundred pounds of body weight was approximately equal, being 6.0 pounds without succulence and 6.2 pounds with succulence.

Effect of Plane of Production on Total Consumption

Both free water and total water consumption were increased when milk production and the associated dry matter intake in feeds were increased.

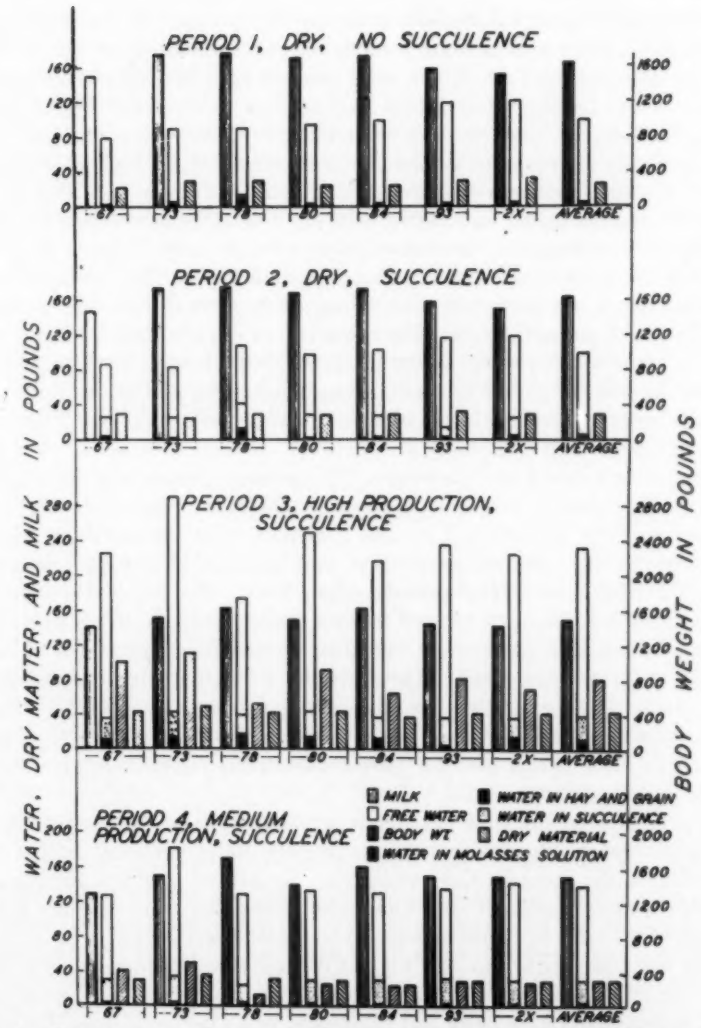

FIG. 1. COMPARISON OF POUNDS OF WATER CONSUMED, DRY MATTER INTAKE, MILK PRODUCED, AND BODY WEIGHT.

The 3-day average for each of the seven cows and for the group is shown for each of the four periods.

The average daily milk production was 82.4 pounds at about peak production and 30.2 pounds 7 to 9 months after freshening. For convenience of discussion the former will be called high production and the latter medium production. High and medium production periods will be compared with the dry period during which the cows received succulent feed since succulence was also fed during both high and medium production. The average water consumption for the seven individual cows and the group average during the three-day periods when the cows were dry, in high production, and in medium production is presented in Fig. 1, Periods 2, 3, and 4, respectively. Succulence was fed in each of these three periods. For comparison with average water consumption average body weights and the average dry matter consumed are also presented for the three periods.

The highest one-day production by any of the cows during high production was 114.4 pounds of milk. The seven individual cows, during the three-day high production period, averaged daily: 110.6 pounds, 100.4, 91.3, 85.2, 71.1, 65.9, and 54.3. During the medium production period the three-day average milk production listed in corresponding order was: 49.5 pounds, 40.8, 26.0, 28.9, 28.2, 24.2, and 13.9.

Free water drunk daily averaged 73.5 pounds during the dry period, 109.7 pounds during medium production, and 191.4 pounds during high production (Fig. 1, Periods 2, 4, and 3, respectively). Total water intake daily for the dry, medium production, and high production periods averaged 102.6, 140.3, and 231.4 pounds, respectively. The ratio of free water drunk to milk produced averaged 3.6 to 1 during medium production and 2.3 to 1 during high production. Total water consumed per pound of milk was 5.2 to 1 during medium production and 2.8 to 1 during high production. It would be expected that more water would be consumed for each pound of milk produced during medium production than during high production because water-used-for-purposes-other-than-in-milk represents a larger percentage of the total.

The results of the first two trials while the cows were dry (Fig. 1, Periods 1 and 2) showed that approximately 100 pounds of total water were used under these feeding conditions. By subtracting this 100 pounds of water used for purposes other than milk production from the total water consumed the ratio of the remaining water to milk was found to be 1.3 to 1 during medium production and 1.6 to 1 during high production. The difference might be attributed to the greater work of production as evidenced by 52 pounds more milk daily and 14 pounds, or 45 per cent, more dry matter consumed daily.

During high production the total water consumed per pound of dry matter was 5.3 pounds, while during medium production it was 4.7 pounds. When dry the cows averaged 3.7 pounds of total water per pound of dry matter without succulent feed and 3.4 pounds with succulent and slightly

more dry matter, or an average of 3.6 pounds of water per pound of dry matter for the two dry periods.

When the water in milk was subtracted from the total water consumed, the remaining water per pound of dry matter was 3.7 pounds for both high and medium production, which is very close to the average (3.6 pounds) of the dry periods.

Total water consumed per hundred pounds of body weight averaged 6.0 pounds during the dry period with no succulence, and 6.2 pounds during that with succulence; 9.3 pounds during medium production; and 15.3 pounds during high production. When water in the milk was subtracted from the total water, the remaining water per hundred pounds of body weight was 10.5 pounds during high production and 6.2 pounds during medium production even though the cows averaged the same in weight during both periods. The difference may be attributed to greater dry matter consumption during high production. When the dry matter consumed was approximately the same, as was true during the dry period with succulence (Fig. 1, Period 2) and the medium production period (Fig. 1, Period 4), the same amount of water (6.2 pounds) was consumed per hundred pounds of body weight, provided water in milk was first subtracted. This was true even though there was a difference of 131 pounds, or 9 per cent, in body weight.

These results indicate that under relatively similar climatic and feeding conditions the total water requirement of dairy cows depends on the water in the milk plus a rather definite amount of water per pound of dry matter consumed. Whether or not, with cows differing greatly in weight, the water requirement per hundred pounds of body weight, after water in milk is subtracted, would be rather constant under similar climatic and feed conditions, as herein reported, is not known. With more variation in weight, such as cows of different breeds, the results might not be as uniform as found in these trials on cows of the same breed with relatively little difference in weight.

Time and Quantity of Water Consumption During Day and Night

The time and the amount of free water consumed by the cows during 24-hour periods was carefully checked by means of an automatic self-recording meter. The cows drank more water and drank more often during the day than during the night. Fig. 2 is an individual record of the seven cows with respect to quantity of free water consumed and the time when drunk during each day and night of the four periods. As milk production increased the cows drank more times during the 24-hour period, and a larger proportion of the total water was consumed during the night. The cows were fed four times per day, at 4 and 10 a.m. and p.m. Hay was before the cows at all times. When dry and fed succulence the cows

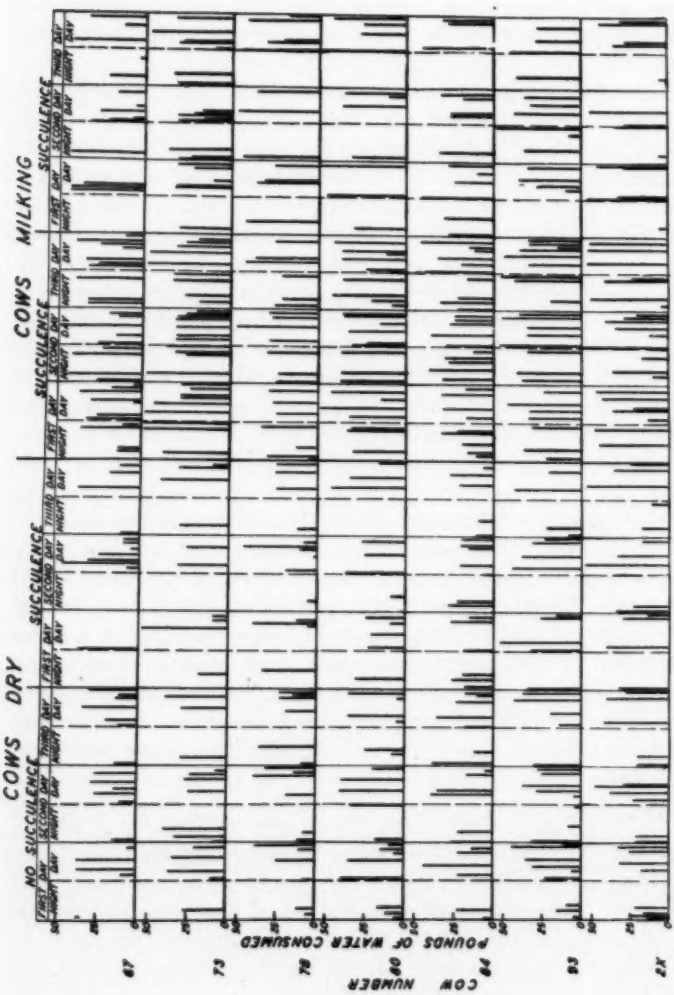

FIG. 2. QUANTITY OF FREE WATER CONSUMED, AND TIME WHEN DRUNK, DURING EACH NIGHT OR DAY OF THE FOUR PERIODS, RESPECTIVELY:

1, dry, without succulence; 2, dry, with succulence; 3, high production, with succulence, and 4, medium production, with succulence.

drank 3.4 times during the day and 1.1 times during the night; while during medium production they drank 1.6 and 3.4 times during night and day respectively, and 3.4 and 5.0 times during high production. Free water consumed in the night was 20 per cent during the dry period, 35 per cent during the medium production period, and 39 per cent during the high production period.

DISCUSSION

The facts most uniformly presented in investigations on the water consumption of dairy cows have been: free water drunk per day and free water per pound of milk produced. Much variation exists in the results because of differences in the factors affecting water consumption. Even similarity in results may mean very little. For example, McCandlish and Gaessler (11) reported the same amount of free water consumed per pound of milk (3.5) as did Cannon and associates (2). The former's results were obtained in midsummer with cows averaging only 16 pounds of milk and being fed soiling crops, while the latter's results were obtained in the winter on cows averaging 26 pounds of milk, being watered and fed hay, silage, and grain in the barn. In the first instance summer heat tended to increase the free water drunk, but at the same time low production and water in soiling crops tended to reduce it; while in the second instance cold weather had a decreasing effect and higher production and feeds of lower water content had an increasing effect.

At different levels of production the ratio of free water to milk should not remain constant even under rather standardized conditions because as production increases the water in the milk represents an increasingly larger proportion of the total water requirements. Reports on the water drunk by cows are of interest in emphasizing the importance of an ample supply, but attempting to arrive at average figures applicable even in a general way to all cows would seem as futile as trying to find the amount and proportion of feeds in a ration for all cows.

Total water, *i.e.*, free water drunk plus water in feeds, is a much better measure of water needed, especially when succulence is fed. Only a few investigators have reported total water consumed. Here again, however, there is lack of uniformity of data because of differences in the cows' milk production, type and protein content of feed, and climatic conditions. Since the water in milk is rather constant the water requirement of a dairy cow was assumed to be the water in milk plus the other water needed. When the water in milk was subtracted from the total water intake, the ratio of the remaining water to dry matter was found to be approximately the same for dry cows, medium producing cows, and high producing cows, even though the dry matter intake varied. This method, *i.e.*, water in milk plus a rather definite amount of water per pound of dry matter, would seem to be the most dependable method of measuring the water requirements of

dairy cows. The method harmonizes with the conclusions of Ritzman and Benedict (15) after conducting digestion trials on steers. They state, " . . . the amount of dry matter ingested determines to a large extent the amount of water that must be consumed to soften it. . . ."

SUMMARY AND CONCLUSIONS

1. Addition of succulence to the ration caused a reduction in the amount of free water drunk, but the total water intake remained approximately the same.

2. Under similar conditions, dry cows drank an average of 73.5 pounds of water daily; medium producing cows (30.2 pounds milk) drank 109.7 pounds; and high producing cows (82.4 pounds of milk) drank 191.4 pounds. The ratio of free water to milk was 3.6 to 1 for medium producers and 2.3 to 1 for high producers.

3. Total water intake averaged daily 102.6 pounds for the dry period, 140.3 pounds for the medium production period, and 231.4 pounds for the high production period. The ratio of total water to milk was 5.2 to 1 during medium production and 2.8 to 1 during high production.

4. The ratio of total water to dry matter consumed was 3.6 to 1, 4.7 to 1, and 5.3 to 1 for the dry, medium production, and high production periods respectively. When water in milk was subtracted from total water the ratio of the remaining water to dry matter was approximately the same (3.7 to 1) for all three periods.

5. Under relatively similar climatic and feeding conditions the total water requirements of dairy cows seems to depend on the water in milk plus a rather definite amount of water per pound of dry matter consumed.

6. Total water per hundred pounds of body weight varied during the three periods, but when water in milk was subtracted the remaining water per hundred pounds of body weight was the same (6.2 pounds) whether the cows were dry or producing, provided the same amount of dry matter was ingested.

7. The average number of times that the cows drank during the day and night was as follows: dry period, 3.4 times during the day and 1.1 during the night; medium production period, 3.4 times during the day and 1.6 during the night; and high production period, 5.0 during the day and 3.4 during the night. Of the free water drunk in 24 hours, during the dry period, only 20 per cent was consumed at night, during the medium production, 35 per cent, and during high production, 39 per cent.

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American Dairy Science Association Announcements

WESTERN DIVISION

The proceedings of the meeting of the Western Division of the American Dairy Science Association have been mimeographed in full, including all papers presented. The meeting was held in the Multnomah Hotel in Portland, Oregon, on October 22, with G. H. Wilster presiding.

In the manufacturing section papers were presented on raw versus pasteurized milk for brick cheese by A. J. Morris, on chlorine sterilization by C. S. Mudge, on mastitis and curd tension by H. C. Hansen, on butter quality by J. A. Nelson, on vitamin D milk by C. L. Roadhouse, and on dairy farm milk coolers by Hans Hoffman. In the production section papers were presented on artificially dried pasture herbage by J. C. Knott and R. E. Hodgson, on grazing habits of dairy cows by R. E. Hodgson, on some unsolved feeding problems by I. R. Jones, on the need for simplification of testing dairy cows for production by E. V. Ellington, on the extension program by D. L. Fourt, and on new ideas for dairy cattle shows by H. M. King.

The Western Division sponsors a students' judging contest at the Pacific International Livestock Exposition. First place in judging all dairy products was won by Utah, second place by Washington, and third place by Montana. In judging all breeds of dairy cattle first place was won by Washington, second by Idaho, and third by Oregon.

METHODS OF ANALYZING DAIRY PRODUCTS

The methods of testing dairy products which were recently published in the Journal may still be secured from R. S. Breed, Geneva, N. Y., at 50 cents per copy.

STANDARD METHODS OF MILK ANALYSIS

The American Public Health Association announces the sixth edition of Standard Methods of Milk Analysis. Many important additions and changes occur.

In view of the extensive alterations and additions, it is urged that the Fifth Edition published in 1927 be discarded. The new edition may be purchased from the American Public Health Association, 450 Seventh Avenue, New York, N. Y., for $1.00.

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